Improving the dynamic stability of electrical power systems via vibration damper that relies on integrating controloptimised with an advanced operational amplifier

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Abstract
The aim of this research is to improve the dynamic stability of electric power systems by introducingadditional damping to the excitationcontrol circuit by means of a vibration damper that relies on integrating the signal provided by an advanced operational amplifier circuit with a negative feedback signal obtained from solving the Riccati equation. This control signal represents different ratios of state variables of the system.To test its effectiveness, the proposed method was applied to a machine-made electrical power systemsynchronouslyconnected to an infinite collector rod viaa power transmission line.The mathematical model is built. The linearity of the power system of degree Thefol the time response of state variables to this was stud the system. This study confirmed that the proposed method generatesufficient negative damping to improve system stability by reducing the vibrations arising from disturbances.

Key words: Power system stability, Optimised control, Operational amplifier, Power systems, Electrical

Introduction

With the growing development of electric power systems and the development of cross-electric power transmission high-tension transmission networks, an increase in the size of the generating units, the use of high-speed excitation systems, interest in studying the transient dynamic stability of energy systems has increased.

Electrical, especially in last four decades. Transient dynamic stability can be defined as system in transient stability if the system can reach the static state or a state close to it when the system is subjected to significant turbulence. By contrast, dynamic stability means the ability of the system to reach the statics when exposed to slight payload changes [13] [12] [11]. As known, the excitation system of synchronised machines is the main control system that directly affectsthe machines. Much attention in scientific articles focused on the development of an appropriateexcitation system model for stability studies of large systems [1] [2][3]. The effect of the excitation system on dynamic stabilityinvolves the addition of negative damping to the system, thereby causing dampening of the vibrations arising from different types of disturbances, such as the load states of the power flowing in the connecting lines that cause the connected machines to vibrate the system. Low frequency vibrations have been observed to cause instability.Furthermore, the dynamic of a system can be classified as follows [4][5].

Mode ite-inter:This type of vibration accompanies agroup of machines on one part of the systemwhich is swinging against agroup of machines in the other part of the systems.The normal frequency of this type ofthe field oscillation between 2–5 HZ.

Local mode: This type accompanies a group of generating units in a station. The generator is connected to a large electrical power system via weak transmission lines. The normalfrequency for this type of vibration is in the 8.1–8.0 Hz range.

Mode system-Intra: This type is created between individual units within a system. It tends to be similar to the second type. Other types with field voltage are associated with a frequency between 3–6 Hz indicated. exciter mode with type [6]. The excitation provided by the excitation system gives sufficient damping to dampen the resulting vibrations. In the system, we secure the additional damping needed by additional control. The aim of the vibration damper, known as a stabiliser is to employ additional throttle control to add damping so that a vehicle of torque is produced. The electrode on the rotor must be phase-compatible with changes in velocity. Different types of vibration damper vary in terms of the control theories involved in their designs. The accompanying issue remains for each type of damper.

The vibrations areas follows:

1 -The combination of vibration dampers within a wide range of operating conditions.

2 -The performance of a vibration damper in cases of failure

In this research, a vibration damper was developed on the basis of integrating the signal provided by an advanced operational amplifier circuit with an inverted optimised control signal resulting from an equation solution (Riccati.) This method has been tested on a machine-wired power system synchronouslyconnected to an infinite collector rod via a power transmission line.

3- Mathematical model

To study the dynamic stability of electrical power systems,the following codes will be usedfor the model transformation of a needed first power system into a linear system around its operating points. Then, the linear model of the system is expressed in the form of the static state represented by the following equation:

X = AX + BU …(1)

Δ Code refers to small changes about operating values

$d/dt =\cdot$ Time differential

ω, δ Angle speed and angle of ability, respectively

e_q'Transient internal motor power

M, DConstant damping and bale torque for the machine, respectively

V_t Voltage on the edges of the machine

E_{fd}Irritable field effort

K_A, T_A Fixed time and profit for the agitated circuit, respectively

V_{ref} Reference voltage

UControl signal

T_{do}'Open circuit transit time constant on the direct axis

$K_1, K_2, \dots \dots \dots, K_6$Calculated constants for the system

fFrequency 50 Hz

sLaplace conversion factor

X_d, X_qSynchronised reactor on the indirect and direct axes, respectively

X_d'Trans-reactor vehicle on the direct axis

R_I, X_IReactive XXX and resistance of the transport line, respectively

G_I, B_IEminence and acceptance of the line, respectively

P_G, Q_GEffective and reactive capacity of generation

A and B are the two system matrices, and X and U are the state variable beam and signal beam control, respectively.

From the block diagram shown in Figure (1) which represents a comprised electrical power system from a synchronous machine attached to a final collector rod, we can write the differential equations [16]

$\Delta\dot{\delta} = 2\Pi f \Delta W$…(2)

$$\Delta\dot{W} = -\frac{K_1}{M}\Delta\delta - \frac{D}{M}\Delta W - \frac{K_2}{M}\Delta e_q' \qquad \dots (3)$$

$$\Delta e_q' = -\frac{K_4}{T_{do}}\Delta\delta - \frac{1}{K_3 T_{do}}\Delta e_q' + \frac{1}{T_{do}'}\Delta E_{fd} \qquad \dots (4)$$

$\Delta V_1 = K_5\Delta\delta + K_6\ \Delta e_q'$…(5)

$$\Delta\dot{E}_{fd} = -\frac{K_A K_5}{T_A}\Delta\delta - \frac{K_A K_6}{T_A}\Delta e_q' - \frac{1}{T_A}\Delta E_{fd} + \frac{K_A}{T_A}U + \frac{1}{T_A}\Delta V_{ref} \quad \dots (6)$$

By arranging the previous equations in the form of the sub-state variables, we obtain the equation. The matrix is expressed as

$$\left[\Delta\dot{\delta}\ \Delta\dot{w}\ \Delta\dot{e}_q'\ \Delta\dot{E}_{fd}\ \right] = \left[\Delta\delta\ \Delta W\ \Delta e_q'\ \Delta E_{fd}\ \right] + \left[o\ o\ o\ \frac{K_A}{T_A}\ \right]\Delta V_{ref} + \left[o\ o\ o\ \frac{K_A}{T_A}\ \right]U \dots (7)$$

Then, the fourth-order state variable ray is represented by

$$X = [\Delta\delta \;\; \Delta w \;\; \Delta e_q' \;\; \Delta E_{fd}]^T$$

in the absence of an auxiliary control signal.

Operational amplifiers are generally used to amplify signals in circuit sensitisation, as used in filters for the purpose of compensation [8]. In this study,we apply the advanced type operational amplifier shown in Figure (2) to improve system stability. From the electrical circuit shown in Figure(2), we can deduce the transport function that represents the circuit of the operational amplifier. Thus, we obtain

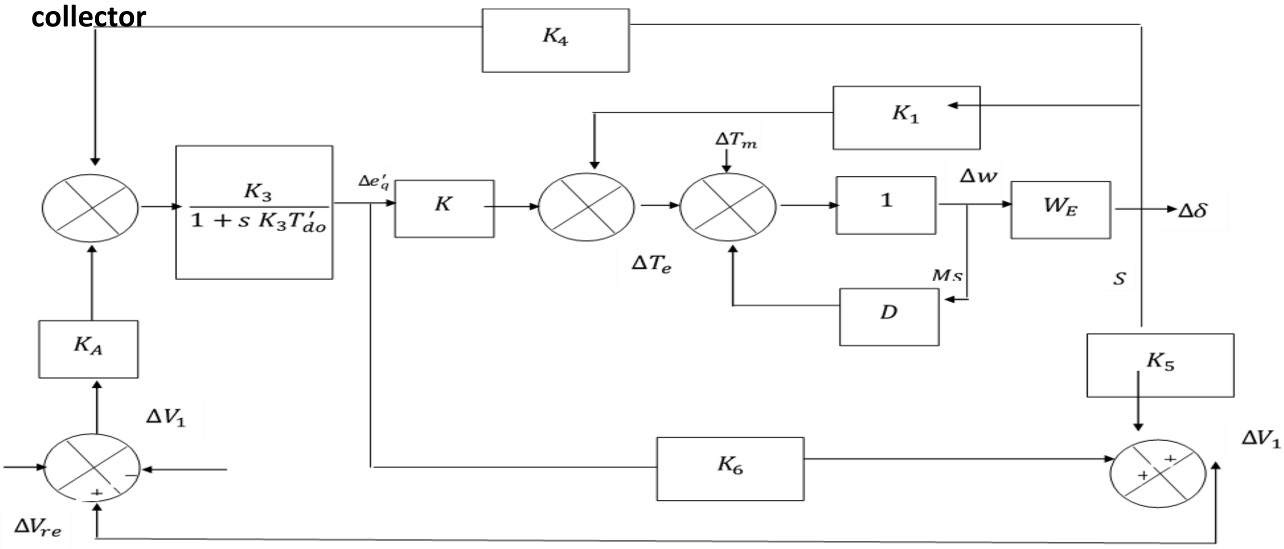
$$\frac{E_o(s)}{E_i(s)} = K_c\left(\frac{s+\frac{1}{T}}{s+\frac{1}{\propto T}}\right) \quad \dots (8)$$

Where:

$T = R_1C_1$, $\propto = \frac{R_2C_2}{R_1C_1}$, $\propto T = R_2C_2, K_c = \frac{R_4C_1}{R_3C_2}$.

For $R_2C_2 > R_1C_1$, the advanced type operation amplifier should be $\propto > 1$. The application of this amplifier circuit to the power system is shown in Figure (1). Figure (4), we have

Figure 1: Block diagram of a power system consisting of a single machine in an infinite collector



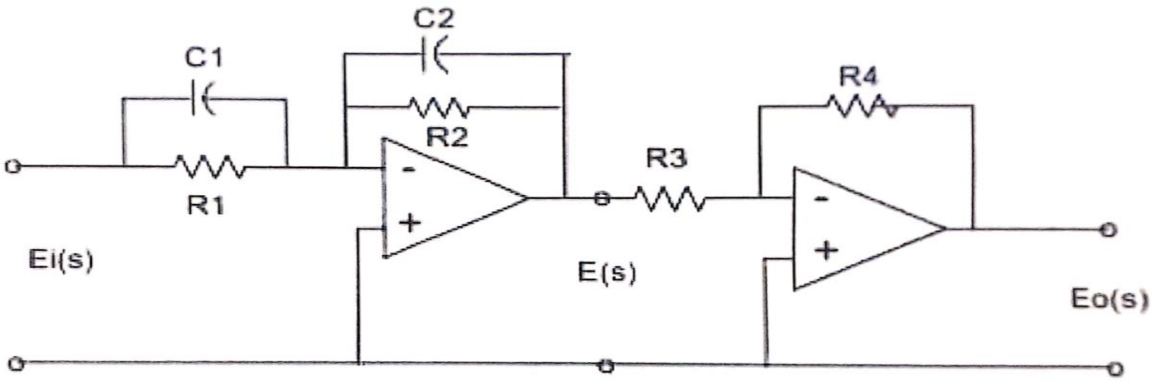


Figure 2: Transfer continued for the operational

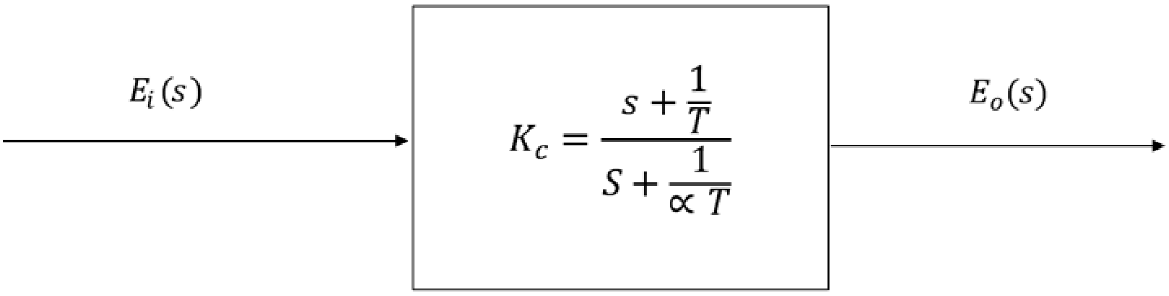


Figure 3: Transfer continued for the operational

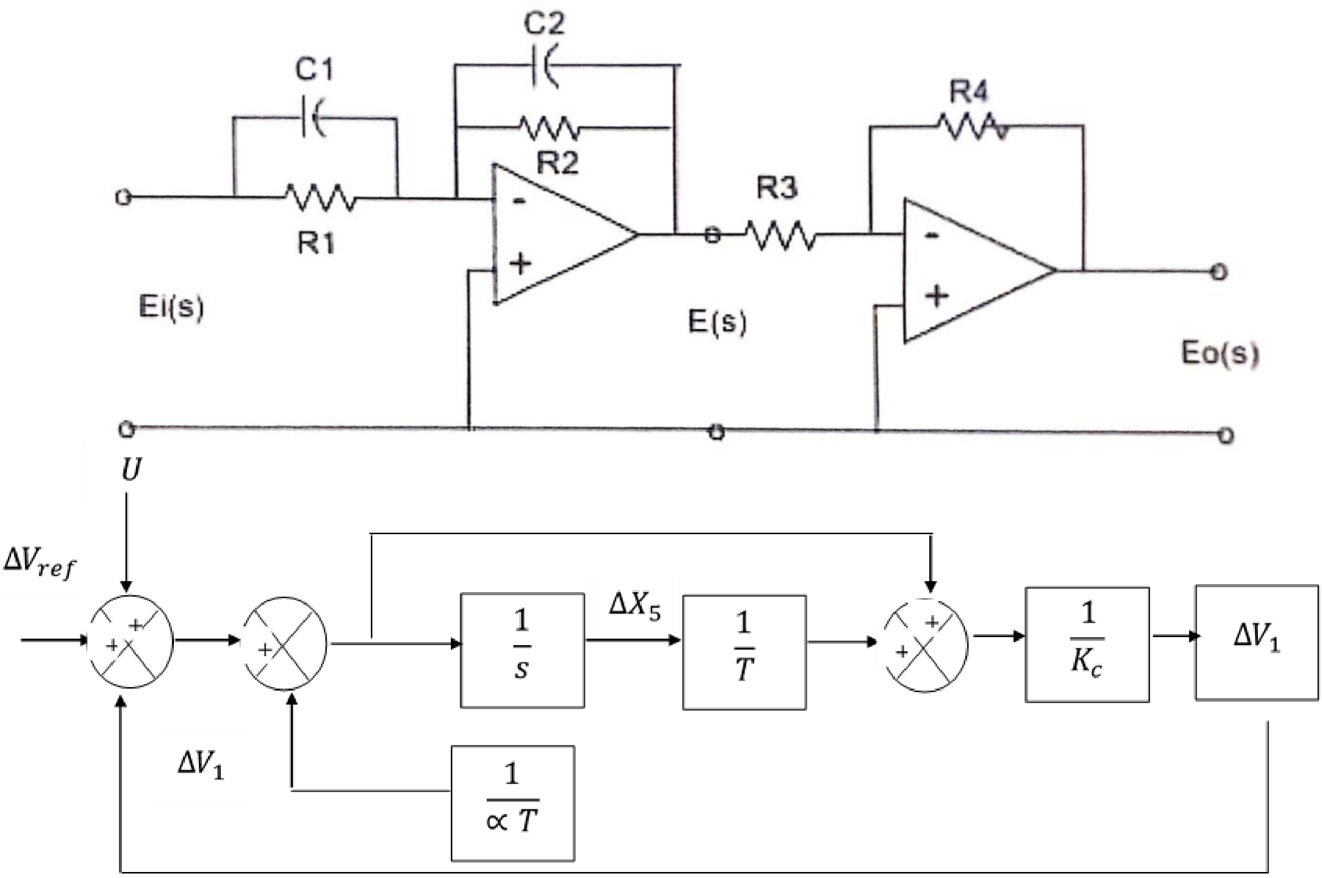


Figure 4: Representation of the system with the operation amplifier circuit

$$\Delta\delta - K_6\Delta e_q' - \frac{1}{\propto T}\Delta X_5 + \Delta V_{ref} + U \qquad \text{... (9)}$$

Then,Equation 6 changed to include the operational amplifier.

$$\Delta\dot{E}_{fd} = -\frac{K_cK_5K_A}{T_A}\Delta\propto - \frac{K_cK_6K_A}{T_A}\Delta e_q' + \frac{K_cK_A}{T_A}\left(\frac{1}{T} - \frac{1}{\propto}\right)\Delta X_5 - \frac{1}{T_A}\Delta E_{fd} +$$

$$\frac{K_cK_A}{T_A}\Delta V_{ref} + \frac{K_cK_A}{T_A}U \qquad \ldots(10)$$

By writing equations in the form 2, 3, 4, 9 and 10 in the matrix form in the space state, we obtain

$$\left[\Delta\dot{\delta}\ \Delta\dot{W}\ \Delta e_q'\ \Delta\dot{X}_5\ \Delta\dot{E}_{fd}\right] = \left[\Delta\delta\ \Delta W\ \Delta e_q'\ \Delta X_5\ \Delta E_{fd}\right] + \left[o\ o\ o\ 1\ \frac{K_c K_A}{T_A}\right]\Delta V_{ref} + \left[o\ o\ o\ 1\ \frac{K_c K_A}{T_A}\right] \ldots (11)$$

Equation (4) represents the system in the presence of an operational amplifier circuit.Avariable beam status of the system is then represented as
$X = [\Delta\delta\ \Delta w\ \ \Delta e_q'\ \ \Delta X_5\ \ \Delta E_{fd}]^T$.
We thus obtain the mathematical model of the fifth degree. In the absence of a control signal, theadditional xxx would be U = O.
The additional optimised control signal U reduces the performance function (9,10):

$$J = \frac{1}{2}\int_o^{\infty} (X^T Q X + U^T R U)dt \quad \ldots (12)$$

It is the Linear function in terms of the state variables of the X system as follows: $U = -KX = -R^{-1}B^T P X$ … (13)
where Q and R are the two balancing matrices,K representsthe feedback matrix,P is the solution of the Riccati linear matrix equation whose value is obtained from solving Equations 7, 9 and 14:
$A^T P + PA - PBR^{-1}B^T P + Q = O$ … (14)
Then, the system achieves optimum control according to the following equation:
$\dot{X} = (A - BR^{-1}B^T P)X + BU$ … (15)

4.Numerical application simulation by computer

The proposed control method was tested with an asynchronous machine power system attached to an infinite collector rod.The machine was equipped with an agitation system of the Mo [IEEE TYPE – 1].
The initial values off the constants associated with the system are as follows:
Synchronous machine constants (U, P) [7]:

$$X_d = 1.5X_d' = 0.16X_q = 1.42$$

$$M = 4.85D = 0.0T_{do}' = 7.56$$

Irritation system:

$$K_A = 200T_A = 0.06$$

Transmission Line:

$$R_I = -0.03X_I = 0.30$$

$$G_I = 0.309B_I = 0.352$$

Operating condition:

$$P_G = 0.9Q_G = 0.71$$

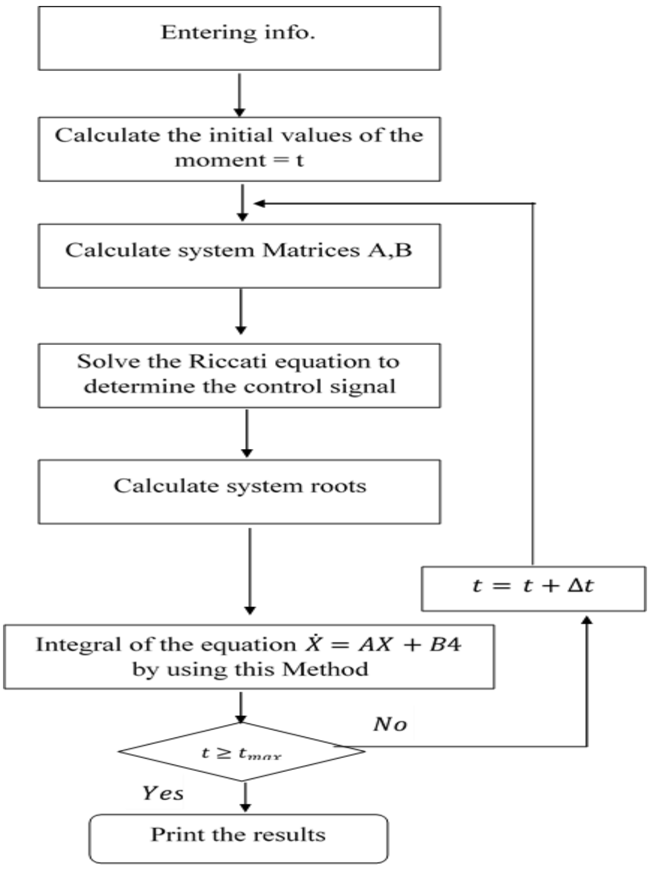
$$V_t = 0.9f = 50\ [HZ]$$

Consonants $K_1, K_2, \ldots, K_6$

$$K_1 = 1.064K_2 = 1.244K_3 = 0.4015$$

$$K_4 = 1.656K_5 = -0.0152K_6 = 0.4781$$

* The mathematical model of a system is built, with its components from a set of differential equations that describes the behaviour of the system.To ascertain the dynamic performance of the system with respect to the time of the integration of these equations using the Range - Kota method, a mathematical program was developed using the Matlab program.This program calculates the initial values. The system then computes the values of the system arrays and subsequently solves the Riccati equation to compute the control signal U and the system roots to determine system stability.Accordingly, the program performs the integration of a set of differential equations to determine the values of the system variables for a certain time.After the values for the system variables are printed, the curves are drawn using Excel.Below we show a flowchart that illustrates the curriculum that served as the solution. To test the effectiveness of the performance of the proposed control system, the system was subjected to a value perturbation. U.p reference voltage of 1.0 for 1 s. The time response of the cases is plotted [15]
The following three:
System response with the presence of the excitation system only.
Using Excel, we generate the flowchart below that illustrates the solution. To test the effectiveness of the performance of the system, the system was subjected to a value pert U.p reference voltage of 1.0 for 1 s. The time resp plotted.
The following three:
System response with the presence of the excitant
2) The response of the system with the presence system with the operational amplifier circuit.
3) System response with the excitation system with an integratedamplifier circuit
* Table (1) liststhe root values of the closed control loop for the previous three states. We notice from the values of the roots that the system, with the presence of the excitation system only, became unstable when subjected to perturbation, as evident from the roots of the characteristic equation because one of the real parts of the roots have a positive value, a feature which suggests that the root is in the right-hand part of the real axis of an s-chart.



* System instability can also be observed through Figures (5), (6) and (7), which

respectively represents the time response of the system variables $\Delta V_t, \Delta w\ and\ \Delta\delta$.After adding the operational amplifier circuit to the system, we note from the values of the roots shown in Table (1) that the real parts of all roots have become negative. This outcome means that the system has become stable. However, a fluctuation of the state variables values persists for the system as shown from Figures (8), (9) and (10) that depict the time response to system variables $\Delta\delta, \Delta w\ and\ \Delta V_t$, respectively, so that when adding the operational amplifier, the values of the constants are$K_c = 1.0, \propto = 0.054\ and\ T = 0.346$.
The following as related tags.When adding the advanced operational amplifier circuit with a negative reverse control signal to the system, we notice improved system stability and increased damping. From Table (1) and the field allocated to the roots of the system in Case 3, we observe the left shift of the values of the real parts. The real axis.Figures (11), (12), (13) and

Operational preamplifier with optimum control	With the addition of the preamplifier operational advanced	With only an irritation system
–82.018	–68.707	–9.29 ± 12.225 i
–22.641	–26.343	0.056 ± 7.466 i
0.462 ± 9.642 i	–0.207 ∓ 7.529 i	
–0.814	–0.943	

Table (1) System roots

(14) represents the time response to the state variables of the system $\Delta V_t, \Delta w, \Delta\delta\ and\ U$, respectively clearly indicate that the system has died down. Figure (11) depicts the control signal for the feedback resulting from the solution and the Riccati equation which is equal to

$$U = 0.135\ \Delta\delta - 4.373\ \Delta w + 0.388\ \Delta e'_q + 4.173\ \Delta X_s + 0.003\ E_{fd}$$

The value of this control signal can be changed depending on the values chosen for the R and Q balancing matrices. That value was chosen here so that R= [1] is the diagonal budget matrix $Q = [0.041 \quad 0.002 \quad 0{:}002 \quad 30.002 \quad 0.001]^T$

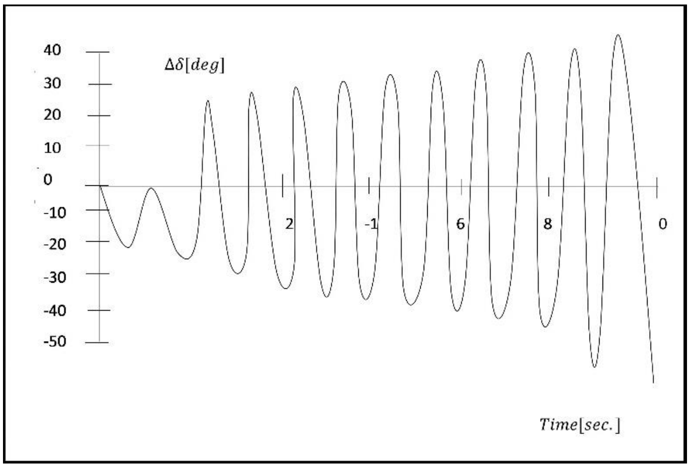


Figure (5): The temporal response to change of power angle in the presence of the excitation system only

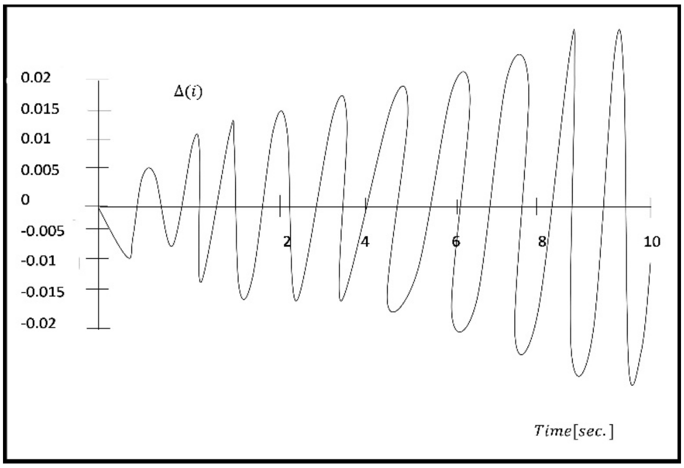
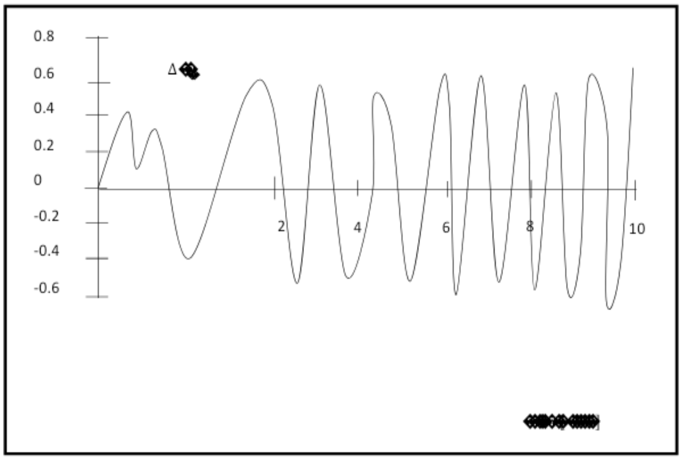
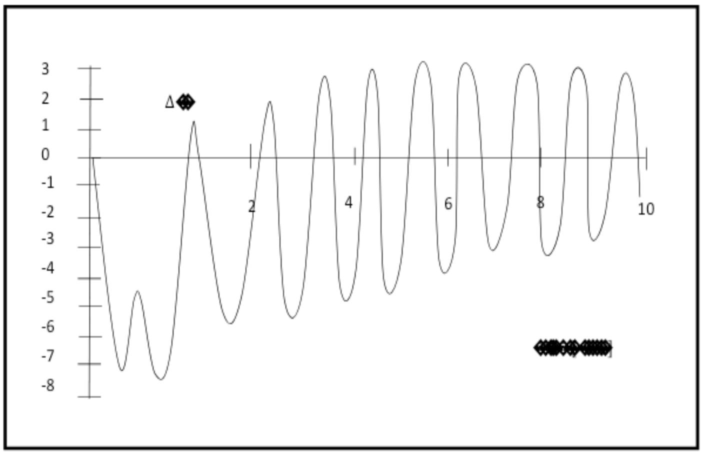
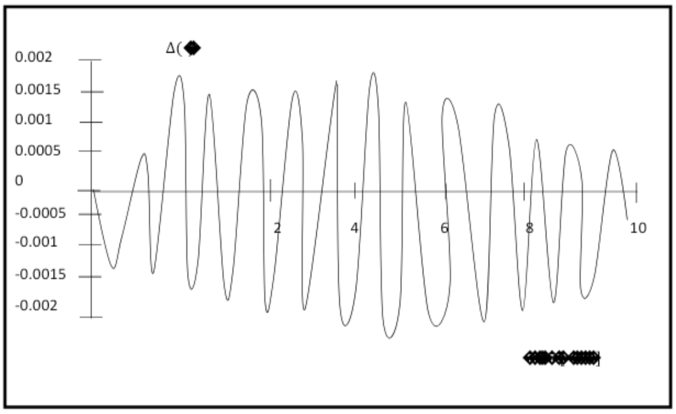


Figure (6): The temporal response to change of velocity with the excitation system only







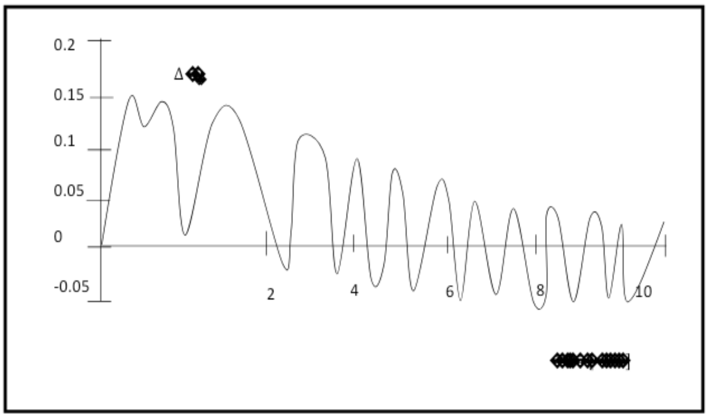
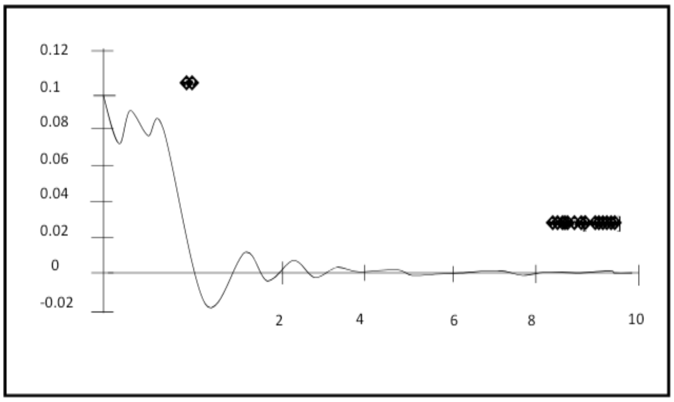


Figure (9): Time response to speed change with the operational amplifier

Figure (10): Time response to terminal voltage change in the presence of the operational amplifier



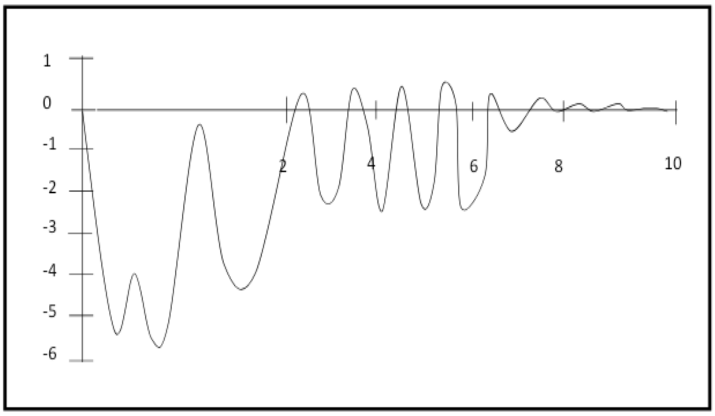


Figure (11): Time response to change of control signal

Figure (12): Time response to power angle change with the operational amplifier with optimum control

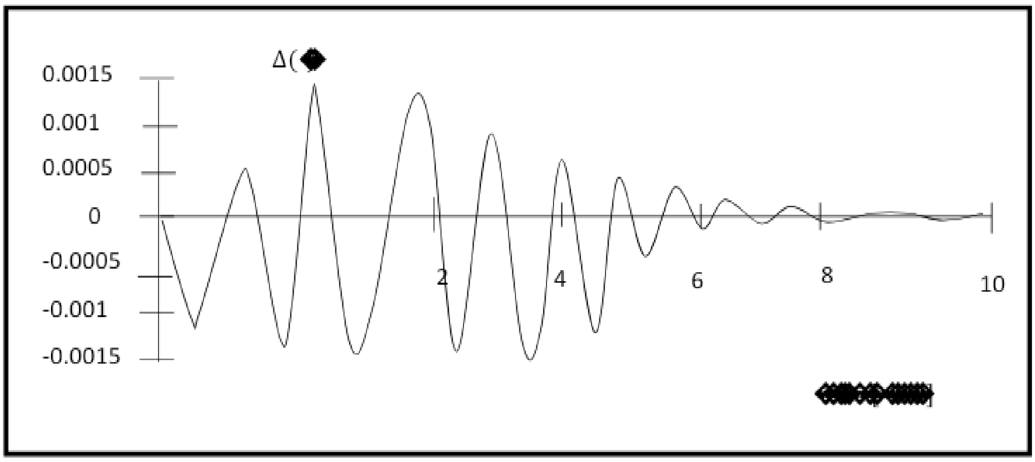


Figure (13): Time response to changing velocity in the presence of an operational amplifier with optimal control

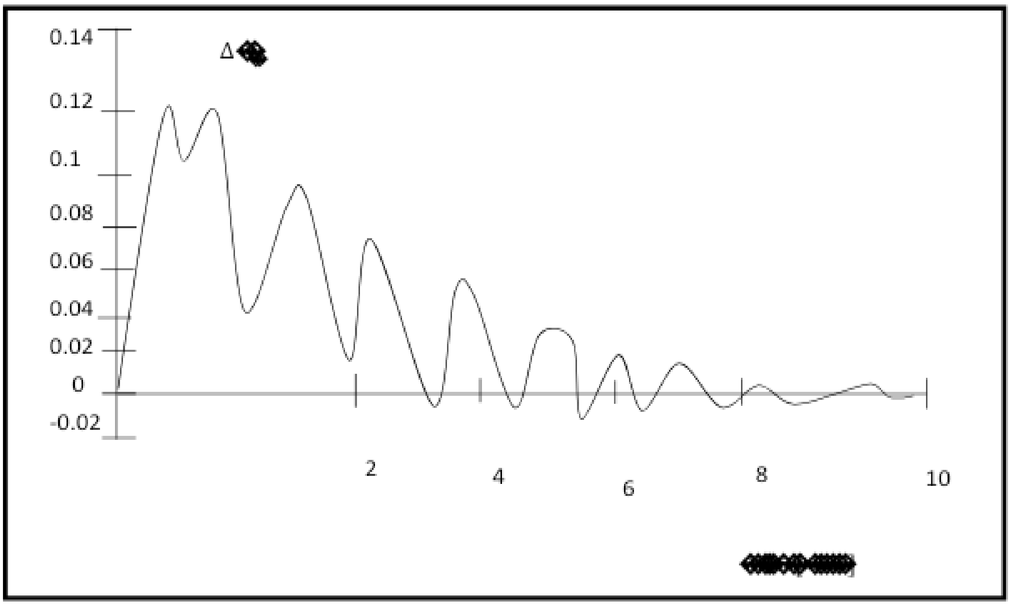


Figure (14): Time response to terminal voltage change in the presence of the operational amplifier with optimum control

Conclusion

This work proposes a method for improving the dynamic stability of electrical power systems. This technique works by adding negative damping from a principle-based vibration damper on the signal provided by an advanced operational amplifier plus the feedback signal negativity resulting from optimal control. The time response to state variables was studied.The system does this in the presence of excitation only when adding the operational amplifier.Then, in the operational amplifier with the feedback signal, this study confirms that those kind of dampers generate good vibration damping and improvesthe performance of the dynamic of the entire system.

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