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Damping Shaft Torsional Oscillations in Dual Excited Turbo Generators

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Abstract. Technical advantages of utilizing the two field systems of the Dual Excited Synchronous Generator **(DESG)** for damping inertial and unstable torsional modes of steam turbo-generators **(T-G)** are considered. This is achieved by adding two auxiliary controllers, one on each field system. The d- axis auxiliary controller is designed to enhance the stability of the inertial oscillatory mode while the q-axis controller is designed to damp the unstable torsional modes. A comparison is made between using either generator or high-pressure turbine speed deviations as the stabilizing signals for the two controllers. The study is conducted on system-I of the second **IEEE** benchmark for the simulation of the sub-synchronous oscillations. A rigorous state space mathematical model has been developed and simulated using **MATLAB** to carry the sought investigations. The pole placement method is used to determine the controller parameters. The results indicate that coordination of the two controllers can significantly increase the power system damping for the inertial and torsional oscillatory modes.

1. Introduction

The problem of torsional oscillations in power systems has received much attention since the two incidents of generator shaft failure at Mohave Power Station in USA[1]. The destructive nature of these oscillations prompted many studies into understanding the factors, which affect them, as well as the promising techniques to counteract them. The countermeasures for self excited torsional oscillations encompass a wide variety of concepts and techniques [2,3,4]. However, there has been no general solution for the torsional problem and in each system the countermeasure should be selected and designed based on the system characteristics.

One of the suggested techniques to improve the electrical power system damping is the use of dual excited synchronous generators (DESG) [5-7], which have d- and q-axis field windings simultaneously. Each field voltage can be controlled separately and hence the angle of the integrated field as well as its magnitude can be changed easily.

As a result, with a good design controllers added to the two excitation systems, the dynamic stability limits of the generator will be improved under any loading condition. Also, it has been found that, the dynamic and transient performance of the machine with rotor angle control is superior especially at extreme leading power factors [8]. Many excitation control strategies for dual-excited synchronous generators have been developed to increase the electrical system damping for the inertial oscillatory mode [9].

Recent studies [10-12] have shown that DESG can also be used to supply power at constant voltage and frequency even when its rotor is driven at a variable speed as it is the case of wind power generation systems. This can be achieved by using two different regulators on the two field systems. One excitation is provided with an automatic voltage regulator (AVR) scheme while the other is provided with an automatic frequency regulator (AFR) scheme. The two-regulation schemes control the excitation currents simultaneously, but act independently to supply power at constant voltage and frequency.

This paper presents a method for damping inertial and unstable torsional modes of T-G sets, based on utilizing the control capabilities of the DESG. The whole idea is to inject the power system with two different control signals through the two-field systems. The d-axis-stabilizing signal is phase and gain adjusted to enhance the stability of the inertial mode while the q-axis-stabilizing signal is designed to stabilize the unstable first torsional mode. The pole placement method in the modal control theory [13] is used to determine the controller parameters. The analysis compares between using the generator speed or high-pressure turbine speed deviations as a feedback stabilizing signals. The study is conducted on system-1 of the second benchmark for the simulation of the subsynchronous oscillations [14]. For carrying out the investigations sought, a rigorous state space mathematical model has been developed and simulated using MATLAB.

2. Dynamic Mathematical Model

Two subsystems are of relevance to this study: The electromechanical part of the power system and the two-excitation systems with their auxiliary controllers.

2.1 Power system

The system under study consists of a 600 MVA steam T-G set which is connected to an infinite bus, as shown in Fig.1. The shaft system of the T-G set comprises four masses: one high-pressure turbine (HP), one low-pressure turbine (LP), generator rotor (G) and exciter (EXC).

2.1.1 *Synchronous generator and transmission system*

Subject to the usual assumptions pertaining to the two-axis theory, the model of the DESG and the transmission system expressed in terms of current and a rotor reference frame takes the following form [15].

$$[L][pi]=[C][i]+[v] \tag{1}$$

where:

$[v] = [v_d \;\; v_q \;\; v_{fd} \;\; v_{fq} \;\; 0 \;\; 0 \; u_{cd} \; u_{cq}]^t$

$[i] = [\; i_d \;\; i_q \;\; i_{fd} \;\; i_{fq} \;\; i_{kd} \;\; i_{kq} \;\; i_{2d} \;\; i_{2q} \,]^t$

[L]and [C] matrices are given in Appendix A.

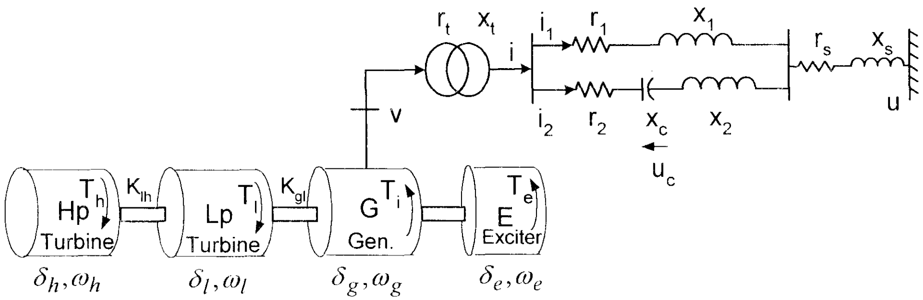

Fig. 1. System under study.

In this model, one damper circuit and one field circuit are considered on each of the d- and q-axis to represent the rotor. The d- and q- axis voltages at the machine terminal are derived in terms of the infinite bus voltage, transmission system currents and impedances and given by:

$$v_d = u_d + x_\ell \, pi_d - \omega_g \, x_\ell \;\; i_q + r_\ell \;\; i_d - x_1 \, pi_{2d} + \omega_g \, x_1 \, i_{2q} - r_1 \, i_{2d} \tag{2}$$

$$v_q = u_q + x_\ell \, pi_q + \omega_g \, x_\ell \;\; i_d \; + r_\ell \, i_q - x_1 \, pi_{2q} - \omega_g \, x_1 \, i_{2d} - r_1 \, i_{2q} \tag{3}$$

The d- and q-axis components of the infinite bus voltage are given by:

$$u_d = u_o \sin(\delta_g) \tag{4}$$

$$u_q = u_o \cos(\delta_g) \tag{5}$$

The series capacitor voltage in the d-q frame is given by:

$$p(u_{cd}) = \omega_g u_{cq} + \omega_o x_c i_{1d} \tag{6}$$

$$p(u_{cq}) = -\omega_g u_{cd} + \omega_o x_c i_{1q} \tag{7}$$

The electromagnetic torque is given by:

$$T_i = i_q\,(-x_d\, i_d + x_{ad}\, i_{kd} + x_{ad}\, i_{fd}) - i_d\,(-x_q i_q + x_{aq}\, i_{kq} + x_{aq} i_{fq}) \tag{8}$$

The system electro-mechanical data is given in [14].

2.1.2 Mechanical system

To study the shaft torsional stresses of the turbine-generator unit, a spring mass model based on discrete mass representation allows the computation of the system variables with the required accuracy. The mechanical system can be described by four-second order differential equations with constant coefficients:

$$[T] = \{[M]p^2 + [D]p + [K]\}[\delta] \tag{9}$$

where

$$[M] = \mathrm{diag}\,[M_h \;\; M_\ell \;\; M_g \;\; M_e]$$
$$[T] = [\,T_{mh} \;\; T_{m\ell} \;\; -T_i \;\; 0]^t$$
$$[D] = \mathrm{diag}\,[D_h \;\; D_\ell \;\; D_g \;\; D_e]$$
$$[\delta] = [\delta_h \;\; \delta_\ell \;\; \delta_g \;\; \delta_e]^t$$

$$[K] = \begin{bmatrix} K_{h\ell} & -K_{h\ell} & 0 & 0 \\ -K_{\ell h} & K_{g\ell} + K_{\ell h} & -K_{g\ell} & 0 \\ 0 & -K_{g\ell} & K_{eg} + K_{g\ell} & -K_{eg} \\ 0 & 0 & -K_{eg} & K_{eg} \end{bmatrix}$$

The shaft system has three natural frequencies (torsional modes) at 24.65 Hz, 32.39 Hz and 51.10 Hz. The first torsional mode is unstable while the second and third modes are marginally stable.

2-2 Excitation system

Type-1 IEEE excitation system shown in Fig.2a is considered in the study. V_{sx} represents the auxiliary stabilizing signal. The state space representation of such excitation system is given by:

$$[pX_{ex}] = [A_{ex}][X_{ex}] + [B_{ex}][U_{ex}] \tag{10}$$

where

$$[X_{ex}] = [\,V_{ax} \;\; V_{fx} \;\; V_{bx}]^t$$
$$[U_{ex}] = [\,V_{ref}\; V \;\;\; V_{sx}]^t$$

where

$\mathbf{V}_{ax}$ is the output of the amplifer;
$\mathbf{V}_{bx}$ is the output of the stabilizing loop.

[Aex] and [Bex] are derived from the block diagram. The transfer function of the auxiliary controller used for either **d-** axis or **q**-axis is shown in Fig.2b, and is given by:

$$H_x(p)=\frac{K_{xw}p}{1+T_{xw}p}K_x\left(\frac{1+T_{1x}p}{1+T_{2x}p}\right)^2 \quad (11)$$

The transfer function of the d- or q-axis auxiliary controller is obtained from equation 11 by replacing x by d or q.

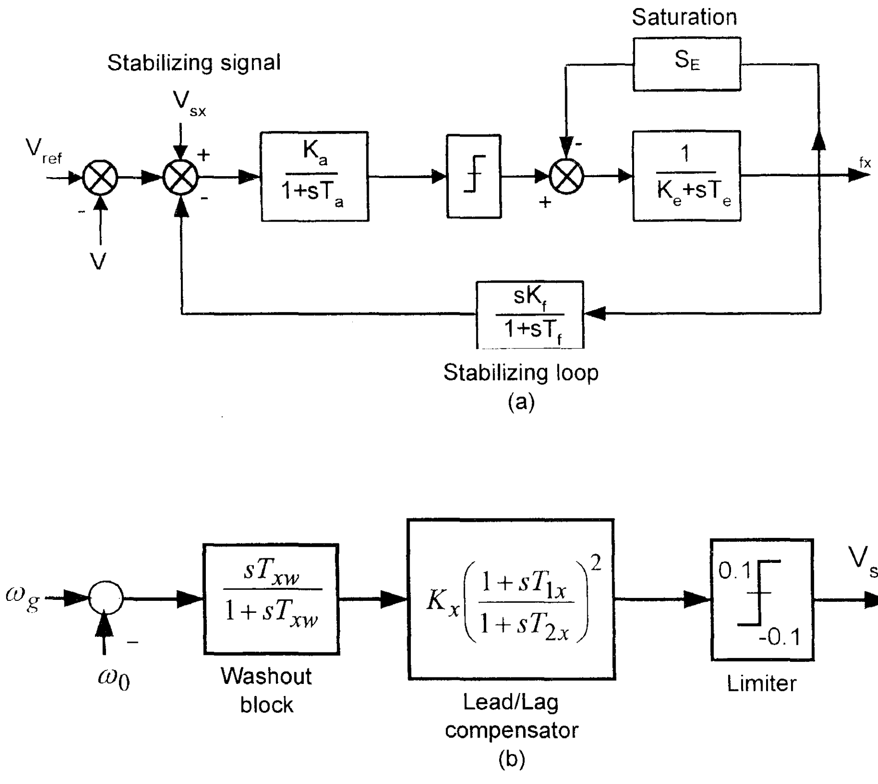

Fig. 2. Block diagram for excitation system and auxiliary controller (a) Excitation system (b) Auxiliary controller.

3. Design of the Auxiliary Controllers

In the design of the auxiliary stabilizers for improving the dynamic stability of power system, the nonlinear system Eqns.(1-10) of the system are linearized around a nominal operating condition. The pole placement method in the modal control theory [13] is then applied to determine a proper set of controller parameters. The linearized state equation of the power system in s-domain is given by:

$$sX(s)=AX(s)+BU(s) \tag{12}$$

where X is the state vector, U is the control vector comprising the auxiliary controllers output signals, and A and B are constant matrices. Equation (12) can be re-written in the following form:

$$\begin{bmatrix} sX_1 \\ sX_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} [U] \tag{13}$$

where

$[X_1]$= [all states excluding that used for controller]^t
$[X_2]$= [state used to feed the auxiliary controller]^t

$$U(s)=H_x(s)Y(s) \tag{14}$$

Y(s) is the feedback signal to the two auxiliary controllers.

$$Y(s)=CX_2(s) \tag{15}$$

$$[B_2]=0 \tag{16}$$

From (13)-(16), we get:

$$\text{Det}[sI-A_{22}-A_{21}(sI-A_{11})^{-1}(A_{12}+B_1H_x(s)C]=0 \tag{17}$$

In the design of the **d**- or **q**-axis controller, it is required to choose a set of parameters with the smallest possible gain since high gain will lead to a deterioration in the terminal voltage profile. The washout time constant $\mathbf{T_{xw}}$ and the denominator time constant $\mathbf{T_{2x}}$ are assumed. A location λ_x for the oscillatory mode is specified. Solving **(17)** after replacing **s** by λ_x yields the gain $\mathbf{K_x}$ and the numerator time constant $\mathbf{T_{1x}}$. In this study the specified locations for the inertial and first torsional modes are:

λ_0 = **-2.01.5 ± j 10.0**
λ_1 = **-3.0 ± j 155.0**

The parameters of the two auxiliary controllers are given in Appendix B.

4. Study Results

Unless otherwise stated, all results are conducted under the following operating conditions: i- The generator delivers **0.9** pu active power to the network; ii-The generator terminal and infinite bus voltages are adjusted to **1.05** and **1.0** respectively; iii-The compensation level is **52%;**

4.1 Eigenvalue analysis

The eigenvalues of the system without controllers are summarized in the first column of Table 1. It is obvious that the first torsional mode is negatively damped while the other torsional modes are marginally stable. The effect of applying the d-axis-stabilizing signal with generator speed as a feedback signal is shown in the second column of Table 1. The results indicate that, the inertial mode stability is enhanced and its corresponding root is located at the prespecified location. On the other hand, there is a destabilizing effect on the first torsional mode. System eigenvalues, when the system is operating under the effect of the q-axis controller, are summarized in the third column. This controller stabilizes the first torsional mode and deteriorates the stability of the inertial mode. Applying the two controllers simultaneously increases the system damping to the inertial and the first torsional mode compared with no control case. The effect on the second and third torsional modes is very small.

Table 1. System eigenvalues with and without controllers

Electro-mechanical modes	Modes	No control	Effect of d-axis control signal	Effect of q-axis control signal	Effect of both d- and q signals
Torsional modes	3	$-0.04 \pm j\,321.26$	$-0.04 \pm j\,321.26$	$-0.04 \pm j\,321.26$	$-0.04 \pm j\,321.26$
	2	$-0.26 \pm j\,203.63$	$-0.25 \pm j\,203.63$	$-0.21 \pm j\,203.63$	$-0.20 \pm j\,203.63$
	1	$+0.38 \pm j\,155.41$	$+0.53 \pm j\,155.41$	$-3.00 \pm j\,155.00$	$-2.75 \pm j\,154.97$
Inertial mode	0	$-0.43 \pm j\,9.98$	$-2.00 \pm j\,10.00$	$+0.19 \pm j\,9.12$	$-1.48 \pm j\,9.35$

Table 2 shows the effect of the two controllers when the high-pressure turbine speed deviation is used as a feedback signal. It can be seen that by activating the d-axis stabilizer alone, the stability of the inertial mode is increased and the instability associated with the first torsional mode is reduced. The q-signal stabilizes the first torsional mode and enhances the inertial mode stability as well. When the two auxiliary controllers are in service together, the system damping to the inertial and first torsional mode is greatly increased compared with the case obtained from Table 1.

In order to check the robustness of the proposed controller under different values of compensation level, the decrement factor of the inertial, first and second torsional modes are obtained and plotted in Fig.3. It is clear that, the proposed method is quite robust regarding the stability of the inertial mode. The proposed controllers increase the electrical system damping to the first torsional mode but unfortunately in a narrow range of series compensation around the point used in the design. Outside this range the controller has a destabilizing effect on the stability of the first mode. In this regard it is recommended to use self-tuning regulator instead of constant parameter controller.

Table 2. System eigenvalues with and without controllers (ω_h is used as a feedback signal

Electro-mechanical modes	Modes	No control	Effect of d-axis control signal	Effect of q-axis control signal	Effect of both d- and q signals
Torsional modes	3	-0.04 ± j 321.26	-0.04 ± j 321.26	-0.04 ± j 321.26	-0.04 ± j 321.26
	2	-0.26 ± j 203.63	-0.21 ± j 203.63	-0.45 ± j 203.65	-0.42 ± j 203.55
	1	+0.38± j 155.41	+0.09 ±j 155.44	-3.00 ± j 155.00	-3.13 ± j 156.41
Inertial mode	0	-0.43 ± j 9.98	-2.01 ± j 10.00	-0.57 ± j 10.28	-2.24 ± j 10.77

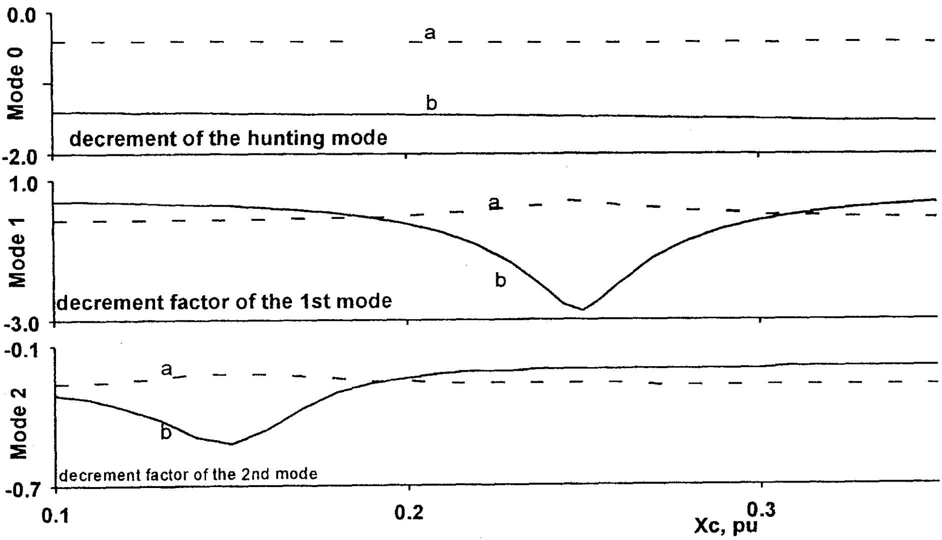

Fig.3. Decrement factors of the inertial, first and second torsional modes against series compensation: (a) no control (b) with control.

Tables 3 and 4 list the system eigenvalues under different values of real power generation, Pg, and various values of generator terminal voltages, V, respectively. The results indicate that, the controller performance is quite enhanced with the increase in the generator real power. The destabilizing effect of the q-axis controller on the inertial mode is more pronounced at light loading conditions. Increasing the terminal voltage will enhance the stability of the first torsional mode and reduce the system damping to the inertial mode.

Table 3. Effect of varying generator output power

Electro mechanical modes	Modes	Pg=0.5 Without controllers	Pg=0.5 With cntrollers	Pg=0.9 Without controllers	Pg=0.9 With controllers
Torsional modes	3	-0.04 ± j 321.26	-0.04 ± j 321.25	-0.04 ± j 321.26	-0.04 ± j 321.26
	2	-0.16 ± j 203.65	-0.08 ± j 203.46	-0.26 ± j 203.63	-0.20 ± j 203.63
	1	+0.35 ±j 155.64	-1.73 ± j 153.00	+0.38 ±j 155.41	-2.75 ± j 154.97
Inertial mode	0	-0.28 ± j 9.42	-0.21 ± j 9.69	-0.43 ± j 9.98	-1.48 ± j 9.35

Table 4. Effect of varying generator terminal voltage

Electro mechanical mode	Modes	V=0.9 Without controllers	V=0.9 With controllers	V=1.05 Without controllers	V=1.05 With controllers
Torsional modes	3	-0.04 ± j 321.26	-0.03 ± j 321.26	-0.04 ± j 321.26	-0.04 ± j 321.26
	2	-0.27 ± j 203.62	-0.22 ± j 203.79	-0.26 ± j 203.63	-0.20 ± j 203.63
	1	+0.21 ±j 156.62	-2.48 ± j 157.30	+0.38± j 155.41	-2.75 ± j 154.97
Inertial mode	0	-0.18 ± j 8.31	-2.49 ± j 7.80	-0.43 ± j 9.98	-1.48 ± j 9.35

4.2 Simulation results

To further demonstrate the effectiveness of the proposed controller, time domain approach based on a nonlinear system model for computer simulations of the system when subjected to a disturbance is carried out in this section. All system nonlinearities such as exciter ceiling and control signal limiters are included. Fig.**4** and Fig.**5** are, respectively, the dynamic response of the system when subjected to a severe three-phase short circuit. The fault starts at **0.5** second and lasts for **2 cycles** of **60 Hz** base, at the infinite bus without and with the proposed controller respectively. As shown in Fig.**4**, the first torsional mode of the system is unstable and the machine shaft system is subjected to very high stresses. On the other hand, Fig.**5** shows the system response when subjected to the same disturbance and the proposed controllers are in service. It is clear that the overall damping of the system is positive and the proposed controller enhances the stability of both the inertial and the first torsional mode.

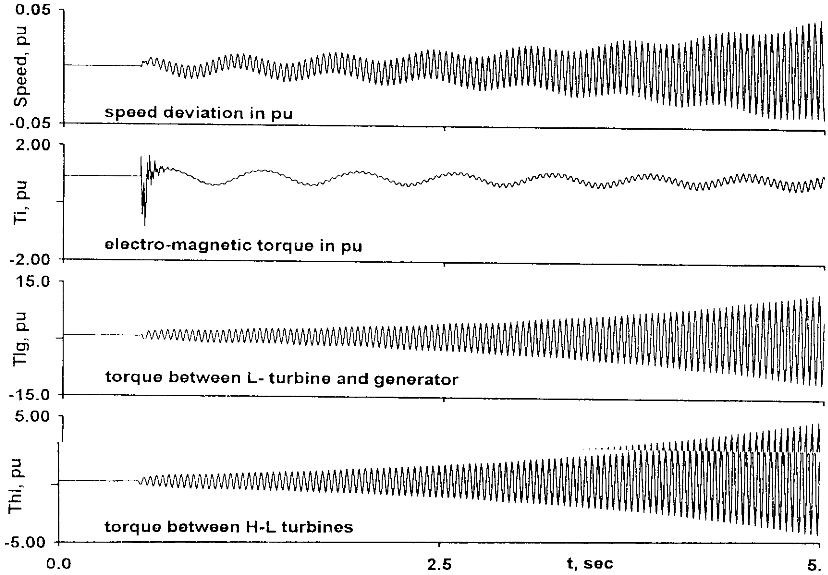

Fig. 4. Transient response of the system when subjected to a 2 cycles of a 3-phase short circuit at the infinite bus without activating the proposed controller.

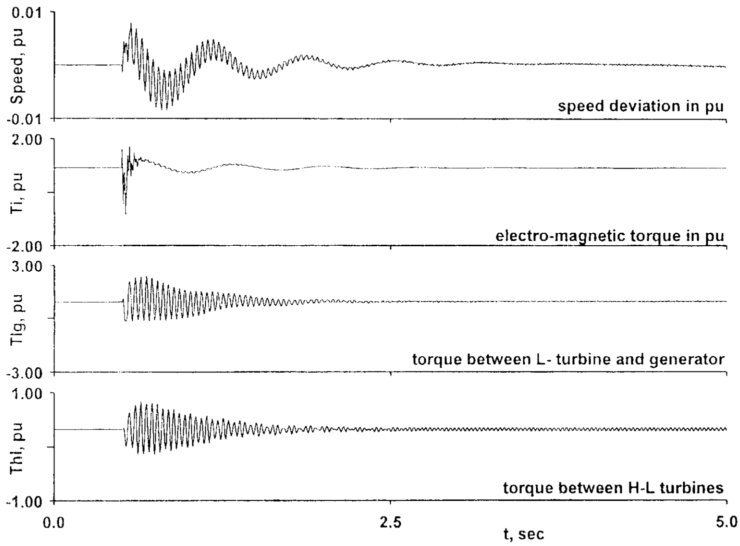

Fig. 5. Transient response of the system when subjected to a 2 cycles of a 3-phase short circuit at the infinite bus with the proposed controller in service.

5. Conclusions

Based on the modal control theory, two auxiliary controllers added to the two-field systems of the DESG are designed. The d-axis stabilizer is used to enhance the inertial mode stability while the q-axis stabilizer is designed to stabilize the first torsional mode. The studies are performed on System-1 of the second IEEE benchmark model, using an eigenvalue method and simulated on the MATLAB program. The investigations show that:

1. The d-axis stabilizer increases the system damping to the inertial mode. This stabilizer is quit robust regarding the stability of the inertial oscillatory mode but it has a negative damping effect on the first torsional mode.
2. The q-axis auxiliary controller stabilizes the unstable first torsional mode. This stabilizer is not quite robust and its parameters must be varied with any change in the system parameters and/or operating condition especially the compensation level. Moreover, it deteriorates the stability of the inertial mode. This effect is more pronounced at light loading condition.
3. Coordinating the d- and q-axis auxiliary controllers will enhance the stability of the inertial and the first torsional modes.
4. The time domain simulation of the system indicates that the proposed method is effective even under a severe disturbance such as a three phase fault.
5. The drawback of the proposed method is that loosing any one of the two regulators will deteriorate the system damping to the oscillatory mode associated with it.

6. List of Symbols

i_d, i_q	d- and q-axis component of the armature currents
i_{fd}, i_{fq}	d- and q-axis field winding currents
i_{kd}, i_{kq}	d- and q-axis damper winding currents
p	differential operator $(d/d(\omega_o t))$
ω_o	electrical system frequency in rad/sec.
r_{fd}, r_{fq}	d- and q-axis field winding resistances.
r_{kd}, r_{kq}	d- and q-axis damper winding resistances
u, v	infinite bus and terminal voltages
u_d, u_q	d and q axis components of infinite voltages
v_d, v_q	d and q-axis components of terminal voltages
v_{fd}, v_{fq}	d- and q-axis field winding exciting voltages
x_{ad}, x_{aq}	d- and q-axis magnetizing reactances
x_d, x_q	d- and q-axis synchronous reactances
x_{ffd}, x_{ffq}	d- and q-axis field winding self-reactances
x_{kkd}, x_{kkq}	d- and q-axis damper winding self reactances
K_f, K_a, K_e T_a, T_f, T_e	excitation system gains and time constants.
$_e,\ _g,\ _l,\ _h$	position angles of the exciter, generator, low pressure and high pressure turbines, respectively

$\omega_e, \omega_g, \omega_l, \omega_h$ Speeds of the exciter, generator, low pressure and high pressure turbines, respectively

M_e, M_g, M_l, M_h Moment of inertia of the exciter, generator, low pressure and high pressure turbines respectively

D_e, D_g, D_l, D_h Damping constant of the exciter, generator, low pressure and high pressure turbines respectively

K_{eg} shaft stiffness between exciter and generator

K_{gl} shaft stiffness between generator and low pressure turbine.

K_{lh} shaft stiffness between low pressure turbine and high pressure turbine

T_{mh} External mechanical torque applied to the high pressure turbine

T_{ml} External mechanical torque applied to the low pressure turbine

$T_{h\ell}$ transfer torque between H and L pressure turbine

$T_{\ell g}$ transfer torque between L-turbine and generator

Ti electromagnetic torque.

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8. Appendix A

$$[L]=\begin{bmatrix} -x_d-x_\ell & 0 & x_{ad} & 0 & x_{ad} & 0 & x_1 & 0 \\ 0 & -x_q-x_\ell & 0 & x_{aq} & 0 & x_{aq} & 0 & x_1 \\ -x_{ad} & 0 & x_{ffd} & 0 & x_{ad} & 0 & 0 & 0 \\ 0 & -x_{aq} & 0 & x_{ffq} & 0 & x_{aq} & 0 & 0 \\ -x_{ad} & 0 & x_{ad} & 0 & x_{kkd} & 0 & 0 & 0 \\ 0 & -x_{aq} & 0 & x_{aq} & 0 & x_{kkq} & 0 & 0 \\ x_1 & 0 & 0 & 0 & 0 & 0 & -x_{12} & 0 \\ 0 & x_1 & 0 & 0 & 0 & 0 & 0 & -x_{12} \end{bmatrix}$$

$$[C]=\begin{bmatrix} r_1+r & -\omega_g(x_q+x_\ell) & 0 & \omega_g x_{aq} & 0 & \omega_g x_{aq} & -r_1 & \omega_g x_1 \\ \omega_g(x_d+x_\ell) & r_1+r & -\omega_g x_{ad} & 0 & -\omega_g x_{ad} & 0 & -\omega_g x_1 & -r_1 \\ 0 & 0 & -r_{fd} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -r_{fq} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -r_{kd} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -r_{kq} & 0 & 0 \\ -r_1 & \omega_g x_1 & 0 & 0 & 0 & 0 & r_{12} & -\omega_g x_{12} \\ -\omega_g x_1 & -r_1 & 0 & 0 & 0 & 0 & \omega_g x_{12} & r_{12} \end{bmatrix}$$

where

$r_{12} = r_1 + r_2$;

$x_{12} = x_1 + x_2$

$r_\ell = r_t + r_s + r_1$

$x_\ell = x_t + x_s + x_1$

9. Appendix B

Excitation system parameters:

k_a=200.0 k_f=0.05 k_e=1.0 T_a=0.34 sec. T_f=1.0 sec.;

Controllers parameters:

K_{dw} = 0.0105 T_{dw} = 2.0 sec. T_{1d} = 0.2892 sec. T_{2d} = 0.05 sec.

K_{qw} = -0.0644 T_{qw} = 2.0 sec. T_{1q} = 0.0885 sec. T_{2q} = 0.004 sec.

إخماد الاهتزازات الالتوائية في المولدات التوربينية ثنائية المجال

رزق محمد السيد حموده

قسم الهندسة الكهربائية ، جامعة الملك سعود ، صندوق بريد ٨٠٠ ،
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ملخص البحث. تعددت الدراسات الخاصة بالآثار المدمرة للاهتزازات الالتوائية للمولدات البخارية الكبيرة للتعرف على الأسباب وكذلك الحلول التي يمكن من خلالها تلافي مثل هذه الاهتزازات . ورغم هذا، لا يمكن القول إنه قد تم إيجاد حل نهائي لهذه المشكلة ودائما يعتمد الحل على طبيعة النظام الكهربائي .,قديما كان هناك اقتراح لتحسين استقرار الشبكة من خلال استخدام مولد ثنائي المجال ويمكن من خلال إضافة أجهزة تحكم مساعدة على الدوائر الأساسية لملفي المجالات المتعامدة زيادة قدرة المولد على إخماد الاهتزازات الكهروميكانيكية صغيرة التردد . وحديثاً تأكد من خلال الدراسات أنه يمكن استخدام مثل هذه المولدات في توليد القوى الكهربائية من طاقة الرياح بتردد وفولت ثابتين حتى وإن كان هناك تغير في السرعة الميكانيكية وذلك بالتحكم أيضا في ملتقى المجالات المغناطيسية. يقدم هذا البحث طريقه لإخماد الاهتزازات في المولدات المتزامنة البخارية ثنائية المجال وتتلخص الفكرة في التحكم في تياري المجالين . وتم وضع دائرة تحكم إضافية على دائرة كل ملف من ملفات المجال المغناطيسي وتقوم دائرة التحكم الإضافية المضافة على دائرة ملف المجال المباشر في إخماد الاهتزازات الكهروميكانيكية صغيرة التردد بينما تقوم الدائرة المضافة على الملف العمودي بإخماد الاهتزازات الالتوائية ذات الترددات السابقة لتردد الشبكة . وقد أكدت النتائج إمكانية هذا التحكم وتم عمل اختبار للطريقة المستخدمة من خلال إحداث قصور ثلاثي الطور لمدة دورتين ورفع القصور وحساب الانحراف في سرعة المولد والعزم الكهرومغناطيسي وكذلك العزوم المنقولة على محور الدوران .