Arab Gulf J. Scient. Res., **12** (2), pp.231 - 253(1994)

Improved Stability of Superconducting Turbo-Alternators by Pole- Assignment Techniques

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ABSTRACT. One most important aspect of design of superconducting generators concerns their stability following a major system disturbance. As the superconducting field winding of these generators has a relatively very long time constant, only governor control shall be relied upon to improve their stability. This paper presents the details of design of a state feedback controller, based on pole-placement technique, to improve transient performance of superconducting turbo-alternators, fitted with fast acting electro- hydraulic governors. The results, obtained by computer simulation, establish that such a controller, with a time delay to the control signal, enhances the transient stability of the machine, by rapidly damping the post fault rotor oscillation.

The capability of superconducting materials to carry large DC with no ohmic loss has generated some interest in developing large superconducting generators. The most optimum configuration of such machines, which has evolved after considerable analysis, consists of a central rotor containing superconducting field winding surrounded by an air cored stator, operating at ambient temperature. The superconducting field winding, cooled by liquid helium, is enclosed by two eddy current shields. The stator is enclosed by a laminated magnetic environmental shield (Jones 1969 and Keim and Loskoris 1985). The advantages of these machines, mainly, are enhanced unit rating and efficiency, and reduced unit size and weight.

One most important design aspect of such machines concerns the stability following a major system disturbance like a three phase short-circuit. Being of air-cored design there is a poor magnetic coupling between the armature and the damping screens. Further, low rotor weight will result in low inertia constant. As a result, these machines can be expected to have low damping characteristics and high hunting frequency, which are detrimental to stability. The interaction between the two screen may further aggravate the problem, though the relatively low synchronous reactance may give a higher stability limit.

Conventional power system controllers, which control both, the governor and the exciter in a coordinated manner, are not applicable to superconducting generators, as the field winding of these machines has a relatively long time constant, a matter that leaves governor control option only. Previous work, on this machine, revealed that control of input power, with fast acting governors, based on acceleration feed back, provides positive damping. The acceleration term there, is achieved from speed error by means of phase advance network (Alyan and Rahim 1987). A discrete state-space controller has also been considered (Alyan and Rahim 1988). The controller structure is derived by using linear optimal control theory. However, great effort has to be done to choose the randomly selected weighting matrices.

The objectives of the work described in this paper are to examine the performance of a state variable feedback controller, based on pole-assignment technique to improve the stability of superconducting generators.

1. The Non-Linear Mathematical Model:

For the purpose of analysis, a doubly screened superconducting generator of 2000 MVA capacity (Alyan and Rahim 1988), is assumed to be connected to an infinite bus-bar through a transformer and a double circuit feeder. In addition to the superconducting field winding, the rotor of this machine carries an inner shield and an outer damper screen. The stator carries the stator winding and an environmental screen which constitute the outer body. The machine is represented by the well known Park's d-q axes model (Jones 1969). The two screens as well as the superconducting field winding are each represented by a single coil of fixed parameters as appropriate, in the direct and quadrature axes. Because of the air-cored nature of the machine, the parameters estimation is based upon a three dimensional field model (Rahim *et al.* 1984). The transient model of the machine is given in the Appendix.

The generator is driven by a three stage reheat steam turbine controlled by a fast acting electro-hydraulic governor. The basic parameters of the generator, the turbine, the governor and the transmission line are given in (Alyan and Rahim 1987). The overall system is represented by a set of non-linear differential equations (Alyan and Rahim 1987, 1988, Lowrenson *et al.* 1976 and Pullman and Hogg 1979).

2. Controller Design

2.1 The Linearized Model

The design of a state-variable controller is done, first by reducing the order of the non-linear model, and then linearizing the equations about a chosen steady-state operating conditions. This simplifies the design procedure because it reduces the number of equations, and at the same time provides an adequate representation of the system in the Linearized form.

The ninth order mathematical model of the superconducting alternator, using the d-q representation may be reduced to fourth order model by introducing the following assumptions (Alyan and Rahim 1988). The effect of rates of change of rotor angle and flux linkage in the armature equations are neglected, feeders, transformer, armature and field winding resistances are reduced to zero; the effect of the eddy currents in the outer screen is neglected. The validity of these assumptions stems out of their negligible effects during small disturbances. The field winding reactance is combined with the reactance of the inner screen on the direct axis, thus eliminating the field circuit, while maintaining its effect. The reduction of the model is shown in the Appendix.

It can also be assumed that the combined action of the main inlet and interceptor valves, as well as the effect of the entrained steam in the turbine, may each be represented by a first-order transfer function, thus reducing the governor-turbine system to a second order model.

The Linearized model is of the form;

$$\dot{Y} = A_1 Y + B_1 U \quad (1)$$

where A_1 and B_1 are the state and input coefficient matrices and U is the input vector. The transposed form of the state vector Y is defined by the following equation:

$$Y^t = (\Delta\delta \;\; p\Delta\delta \;\; \Delta\psi_{D2} \;\; \Delta\psi_{Q2} \;\; \Delta G_v \;\; \Delta T_m) \quad (2)$$

where δ is the load angle, ψ_{D2} and ψ_{D2} are the d-axis and q-axis flux linkage of the inner screen respectively, G_v is the governor position and T_m is the mechanical torque. Some of these variables are difficult to measure in practice. This set of variables is transformed to a new set of measurable quantities as follows;

$$X = TY \quad (3)$$

where T is the transformation matrix. The new state-variables are:

$$X^t = (\Delta\delta \;\; p\Delta\delta \;\; \Delta V_t \;\; \Delta I_t \;\; \Delta G_v \;\; \Delta T_m) \quad (4)$$

The new state-space equation is given by:

$$\dot{X} = AX + BU \quad (5)$$

where A is the n × n system matrix and B is n × p input matrix, given by:

$$A = TA_1T^{-1}$$
$$B = TB_1 \qquad (6)$$

The details of the Linearized model are given in (Alyan and Rahim 1988).

2.2 Design Procedure

Consider that the feedback (− KX) is being applied to the system. The closed-loop response is then governed by the following equation:

$$\dot{X} = (A-BK)\,X + BU \qquad (7)$$

The closed-loop eigenvalues are the roots of the determinant $|\lambda I - A + BK|$, where λ contains the eigenvalues and I is the identity matrix. It has been proven (Jan and Sanjoy 1971 and Brown 1985) that, if and only if the open-loop system, (A,B), is completely controllable, then any set of desired closed-loop eigenvalues, $\Gamma = [\lambda_1, \lambda_2, \ldots \lambda_n]$, can be achieved, using a constant state feedback matrix, K. In order to synthesize the system with real hardware, all elements of the gain matrix, K must be real. This will be the case if, for each complex $\lambda_i \in \Gamma$, λ_i is also assigned to Γ.

The open-loop system described by (A,B), is completely controllable, if and only if, the n × n controllability matrix, Q, given below, has rank n (Brown 1985).

$$Q = (B \quad AB \ldots A^{n-1}B) \qquad (8)$$

When the controllability of the open-loop system is identified, the task is then to design a state feedback controller, based on pole-placement technique, which yields the desired closed-loop eigenvalues.

The feedback matrix, K, is determined in such a way that (7) is satisfied for n specified values of $\lambda_i \in \Gamma$. That equation can be rewritten as follows (Brown 1985):

$$\Delta'(\lambda) = |(\lambda I_n - A)(I_n + (\lambda I_n - A)^{-1}BK)|$$
$$= |\lambda I_n - A\,||\,I_n + (\lambda I_n - A)^{-1}BK)| \qquad (9)$$

Let the open-loop characteristic polynomial be Δ(λ); i.e.

$$\Delta(\lambda) = |\lambda I_n - A| \qquad (10)$$

Since $\Delta^{-1}(\lambda)$ is of the same form as the Laplace transform of the open-loop transition matrix, this term can be denoted by $\phi(\lambda)$. The open-loop and closed-loop characteristic polynomials are related by:

$$\begin{aligned}\Delta'(\lambda) &= \Delta(\lambda)\;|\;I_n + \phi(\lambda)BK\;| \\ &= \Delta(\lambda)\;|\;I_r + K\phi(\lambda)B\;| \qquad (11)\end{aligned}$$

The gain matrix must be selected so that, ($\Delta'(\lambda_i) = 0$) for each $\lambda_i \in \Gamma$. This will be accomplished by forcing the $r \times r$ determinant to vanish. Also for any desired λ_i which is a root of $\Delta'(\lambda)$, the following procedure is valid. A sufficient condition for the determinant of ($I_r + K\phi(\lambda)B$) to be zero, if any row or column is zero. Define the j^{th} column of I_r as e_j and define $\psi(\lambda_i) = \phi(\lambda_i)B$ with j^{th} column being ψ_i. Then λ_i is a root of $\Delta'(\lambda)$ if K is selected to satisfy the relation;

$$e_j + K\psi_j(\lambda_i) = 0 \qquad (12)$$

since this forces column j to be zero. Thus:

$$K\psi_j(\lambda_i) = -e_j \qquad (13)$$

This equation by itself is not sufficient for determining K. However, if an independent equation of this type can be found for every $\lambda_i \in \Gamma$, then K can be determined. Controllability of the system, (A,B), is sufficient to guarantee that the rank $\psi(\lambda_i) = 0$ for each λ. If all the desired λ are distinct, it will always be possible to find n linearly dependant columns, $\psi_{j1}(\lambda_1)$, $\psi_{j2}(\lambda_2)$, ...$\psi_{jn}(\lambda_n)$ from the column matrix, $\psi(\lambda)$.

Then:

$$K = -(e_{j1}\; e_{j2}\; e_{j3}\; e_{j4}\; e_{j5}\; e_{j6})\,\psi^{-1}(\lambda) \qquad (14)$$

Equation (14) gives the required gain matrix, K, for any arbitrary assigned closed-loop eigenvalues.

Results

Open-Loop Eigenvalues

The open-loop eigenvalues are the roots of the characteristic equation of the determinant of A. Because of the wide range of operation, it is expected to have different sets of eigenvalues, depending upon the operating point. Hence the operation region is divided into 24 subregions, and a set of six eigenvalues is obtained at the center of each subregion. Table (1) shows the eigenvalues for two operating

Table 1. The open-loop eigenvalues

	P=0.7 & Q=0.5	P=0.7 & Q=−0.5
λ_1	−10.0	−10.0
λ_2	− 3.33	− 3.33
λ_3	− 3.101	− 3.03
λ_4	− 1.069	− 1.115
λ_5, λ_6	−0.065 ± j10.964	−1.115 ± j7.565

points. It can be seen that, the first four eigenvalues are negative real numbers whose values do not change appreciably with the operating point. The last two eigenvalues are complex conjugate pair, which indicate hunting oscillations of the rotor.

The Uncontrolled Response

A symmetrical three phase short-circuit is assumed at the high voltage terminals of the generator transformer. This fault is sustained for a period of 140 ms. The response of the machine is obtained by solving the non-linear model by numerical integration, using Runge-Kutta Vernier method. The rotor angle oscillations, which are of particular interest for both transient stability studies, and for the design of the state feedback controller, are plotted in Fig. 1 and 2 for the two operating points of Table (1). It can be seen that, for both operating points, subsequent to the short-circuit, the rotor sets into a swing mode oscillation, which are poorly damped. It can also be seen that there is a considerable increase in the first swing of the rotor angle from the steady state value. To improve the performance of the system it is essential to achieve higher damping of the rotor oscillations and also reduce the first swing of the rotor angle. The state-space controller, based on pole-placement technique, shall be designed so as to achieve these twin objectives.

Closed-Loop Responses

A schematic diagram of a multi-variable controller, with six state inputs and a single output, is shown in Fig.3 (Pullman and Hogg 1979).

The controller design is based upon the pole-placement technique described earlier, to generate a gain, K, for a set of chosen closed-loop eigenvalues. The above process is repeated, for each of the 24 subregions, till satisfactory damping of the oscillations and acceptable valve movement are obtained. Table (2) shows the final choice of the eigenvalues corresponding to the operating points considered in the previous section.

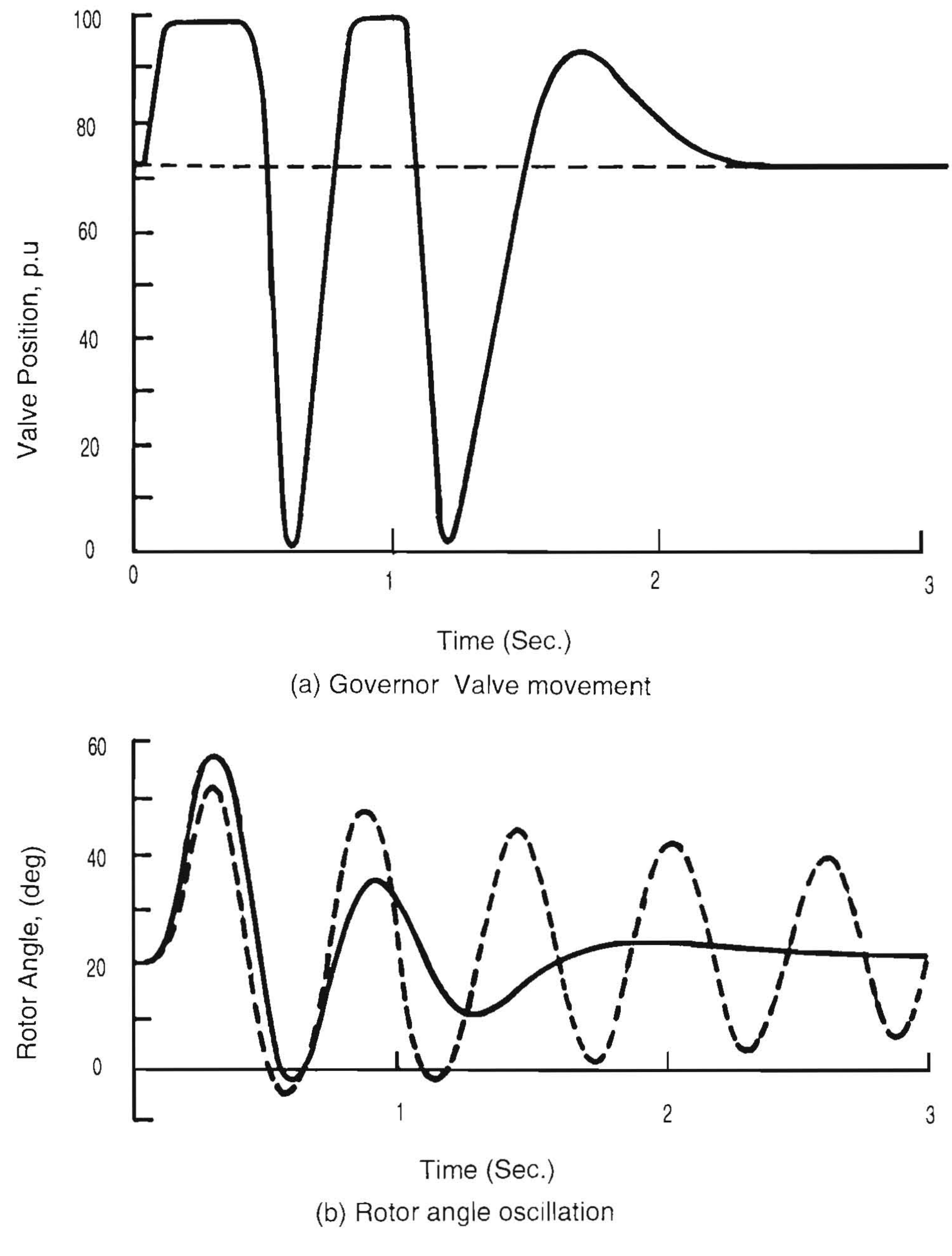
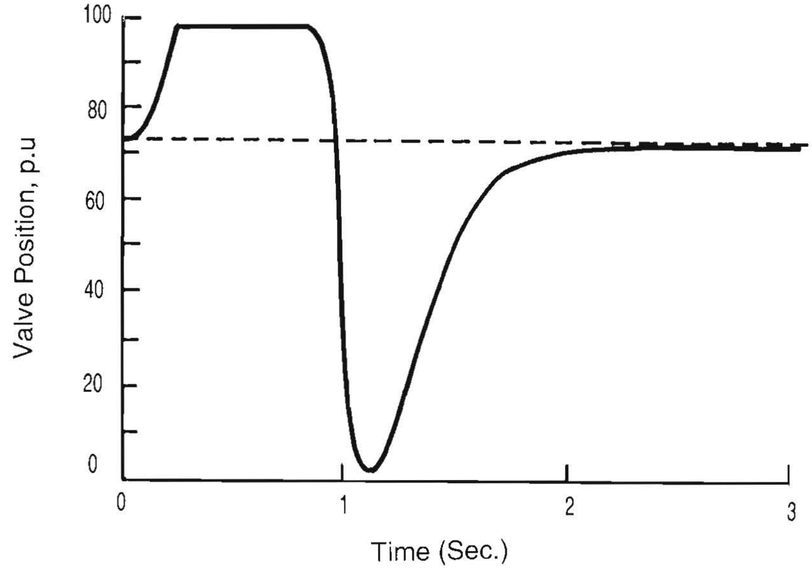
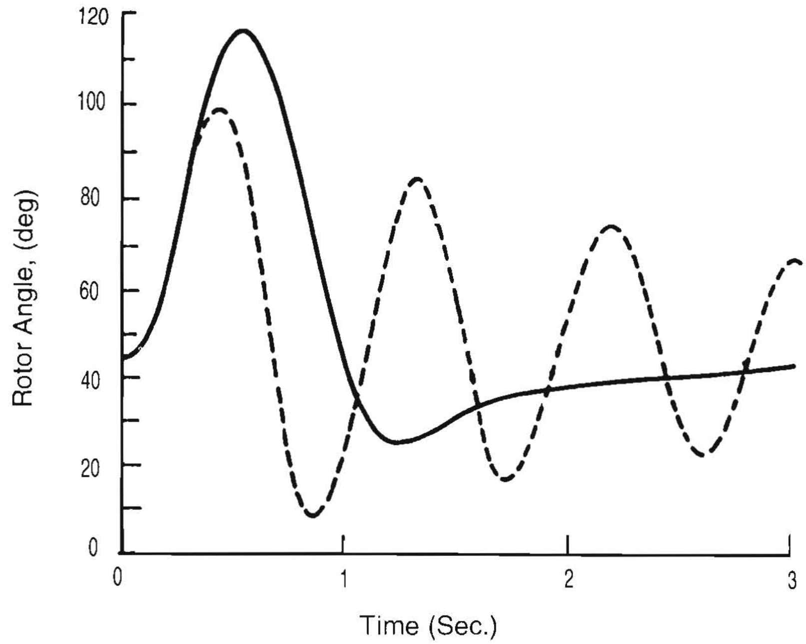


Fig. 1. System performance at P = 0.7 & Q = 0.5 p.u.

——— controlled system
– – – – uncontrolled system



(a) Governor Valve movement



(b) Rotor angle oscillations

Fig. 2. System performance at P=0.7 & Q = 0.5 p.u.

Table 2. The closed-loop eigenvalues

	P=0.7 & Q=0.5	P=0.7 & Q=−0.5
λ_1	−11.0	−11.0
λ_2	− 3.33	− 3.33
λ_3	− 3.1	− 3.0
λ_4	− 1.0	− 1.0
λ_5, λ_6	−2.0 ± j10.9	−2.0 ± j7.5

The corresponding closed-loop response of the valve position and rotor angle are included in Fig. 1 and 2.

It can be observed, from Fig. 1 and 2, that there is a marked improvement in the damping of the rotor oscillations, thus establishing the effectiveness of the controller in damping out the rotor oscillations. At the same time the value movement is confined to two consecutive operations. The increase in the amplitude of the first rotor swing in case of controlled system, as compared to that the uncontrolled system, is due to the increase in input power caused by the full opening of the valves.

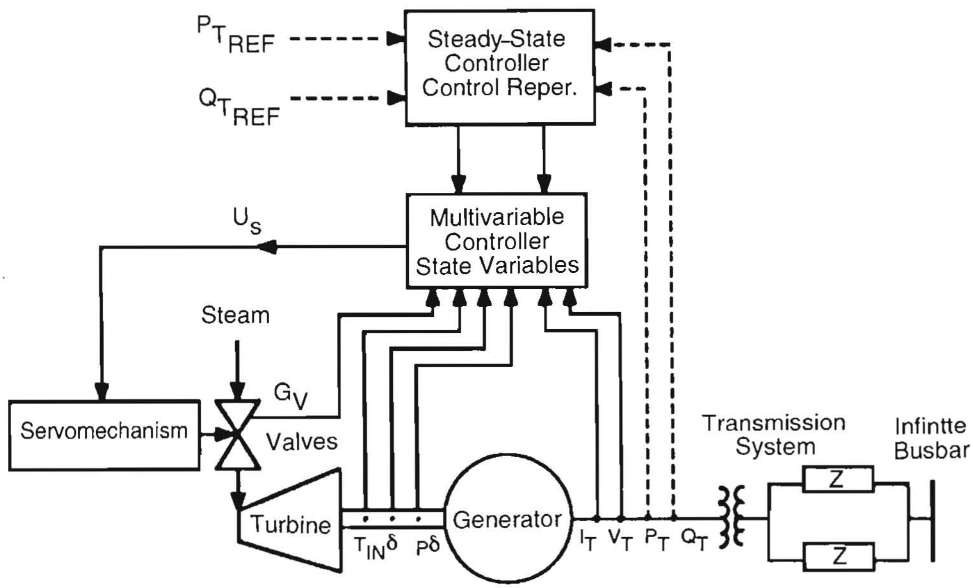


Fig. 3. Schematic diagram of turbo-generator and control system

Innovative Corrections

Though the damping is enhanced, there is an increase in the first swing of the rotor angle. The reason for this is that, following the short-circuit, the governor valve is opened further, thus increasing the mechanical input torque to the generator. It is obvious, that some innovative corrections are needed to nullify this trend.

Effects of varying λ_1 *and* λ_2

In an attempt to contain the increase of the first swing of the rotor angle by preventing the further valve opening, following the short-circuit, it is thought of modifying the closed loop eigenvalues, λ_1 and λ_2, which are associated with the time constants of the valve and the turbine. The chosen values of λ_1 and λ_2 are changed in random combination, and accordingly the feedback controller gains are recalculated. The response of the system is obtained at the two operating points, using the new controller gains. The values of all the other eigenvalues were unaltered during this trial. The response of the system is compared with previous response in Fig. 4 and 5. It can be observed that, for the point with negative reactive power, the increase in the first swing of the rotor angle is considerably reduced, when compared with the previous closed-loop response. However, for the operating point, with positive reactive power, there is no reduction in the first swing of the rotor angle. Also, it can be seen that the degree of damping is adversely affected, a matter that may not be considered satisfactory.

Effects of time delay to control signal

The additional input mechanical power, which is sustained during the period of short-circuit, is responsible for the acceleration of the rotor. It is proposed here, as a corrective measure, to delay the control signal, U_g , to the governor valve. With this modification the system response, at lagging pf. operations, was studied by using time delay of the values; 0.1, 0.2 and 0.5 sec. The corresponding rotor oscillations and valve movements are plotted in Fig. 6,7 and 8, respectively, for the operating point, with positive reactive power. It can be noticed from these figures that, better results, for the first swing, are obtained for long time delays. The reductions in the amplitude of the first swing for the considered delay intervals are about 4°,6° and 8° respectively. This is because the delay of the valve opening prevents the increase in the input power which is behind the overshoot. However this improvement is on the expenses of system damping and valve movement.

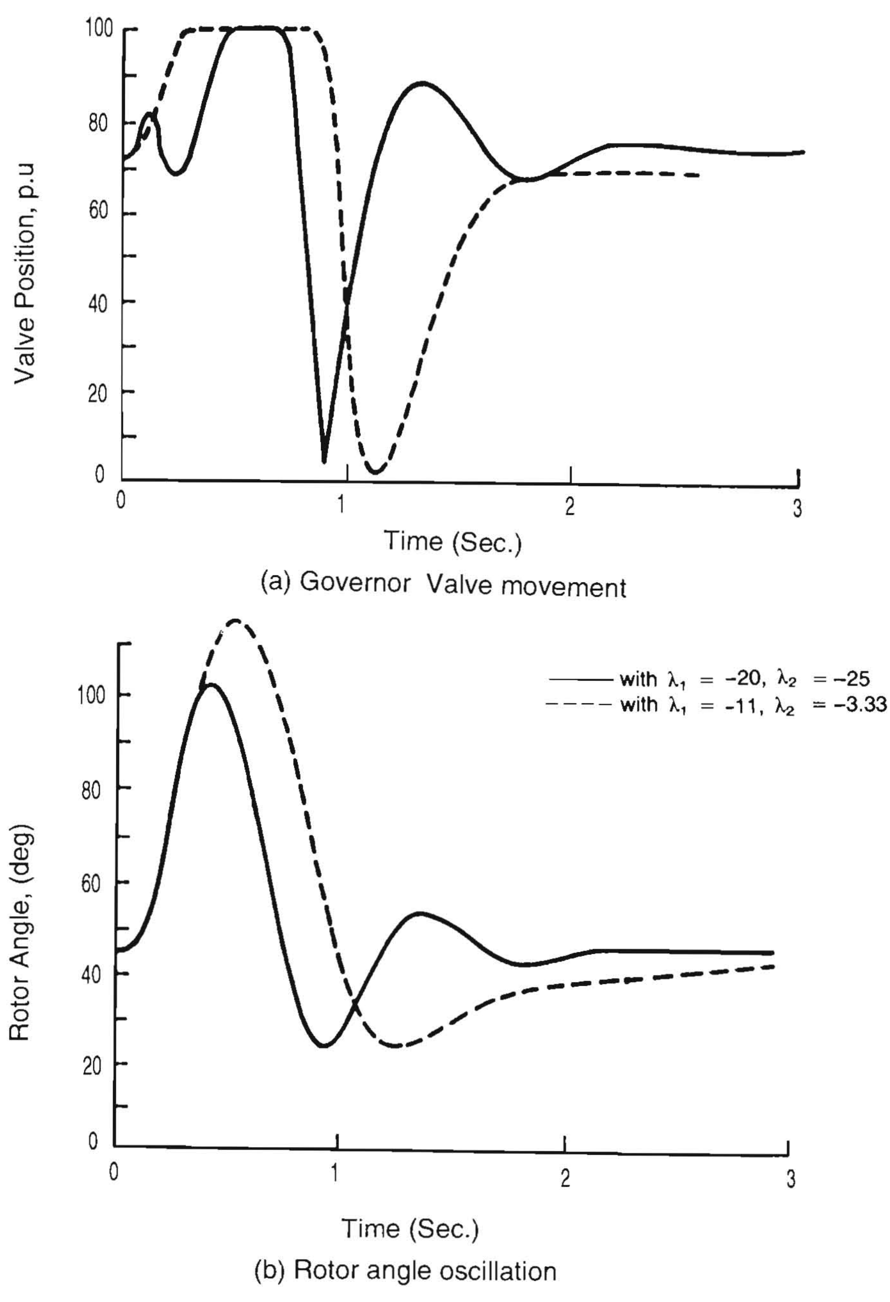


Fig. 4. Controlled System performance at P = 0.7 & Q = - 0.5 p.u.

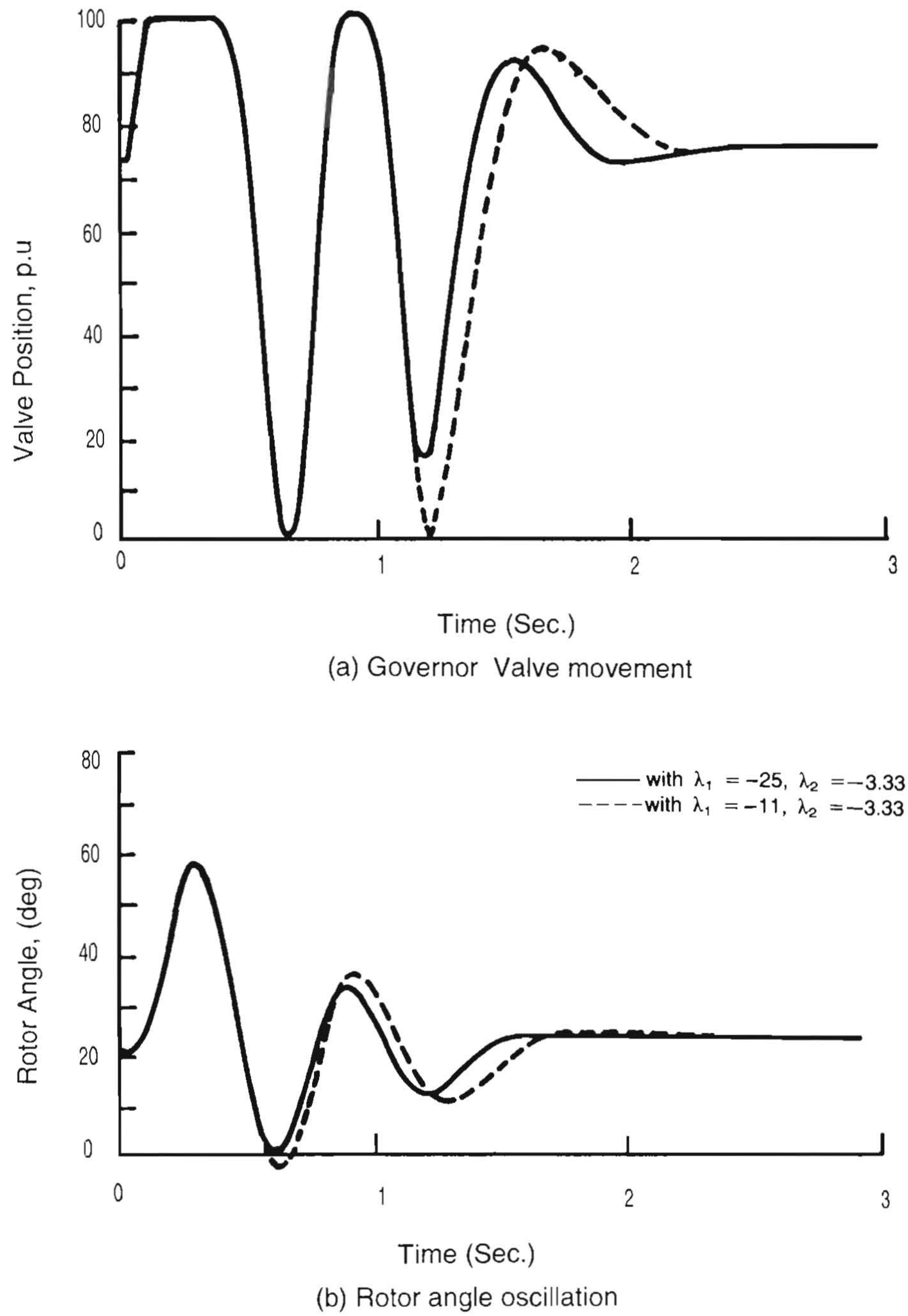


Fig. 5. Controlled System performance at P = 0.7 & Q = 0.5 p.u.

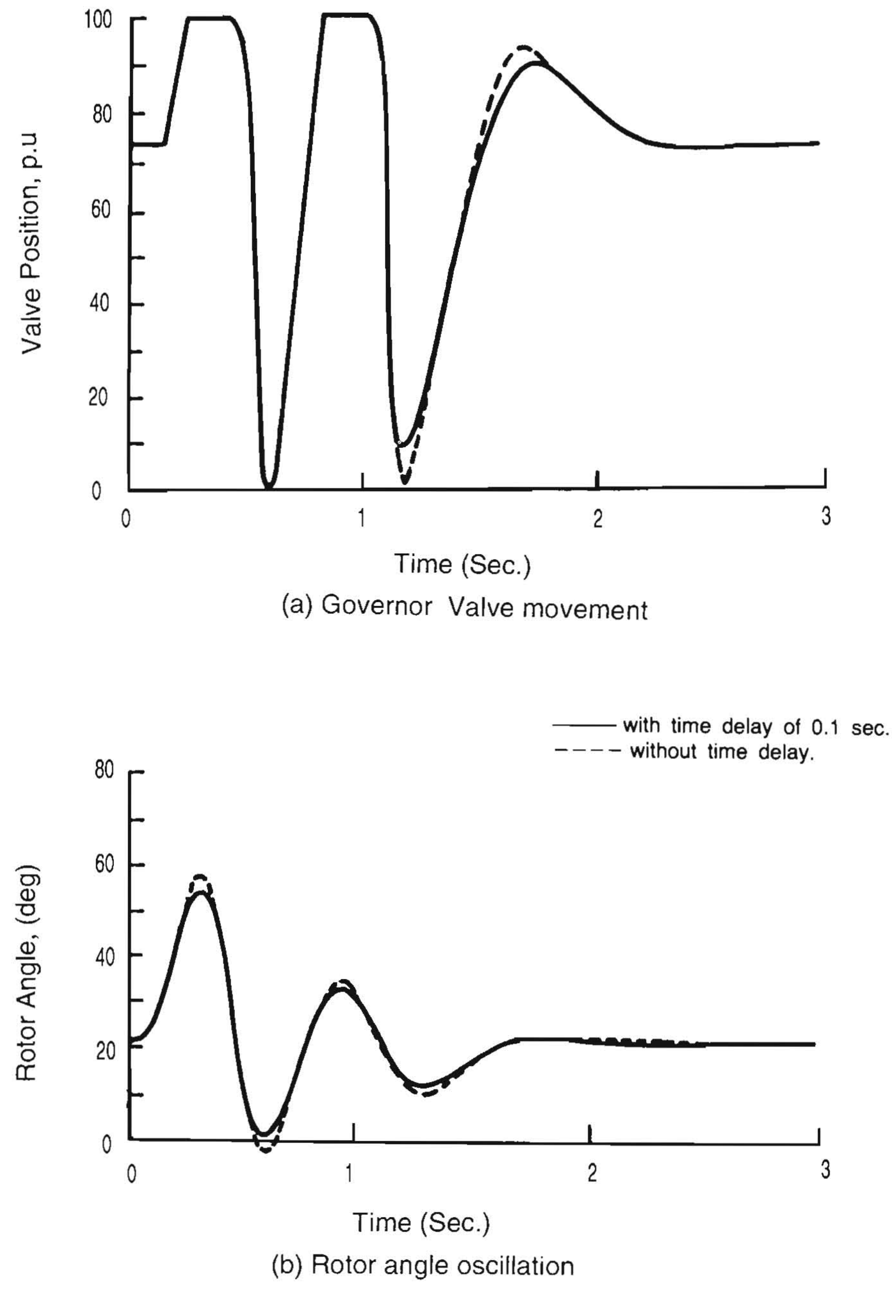


Fig. 6. Controlled system performance at P=0.7 & Q=0.5 p.u.

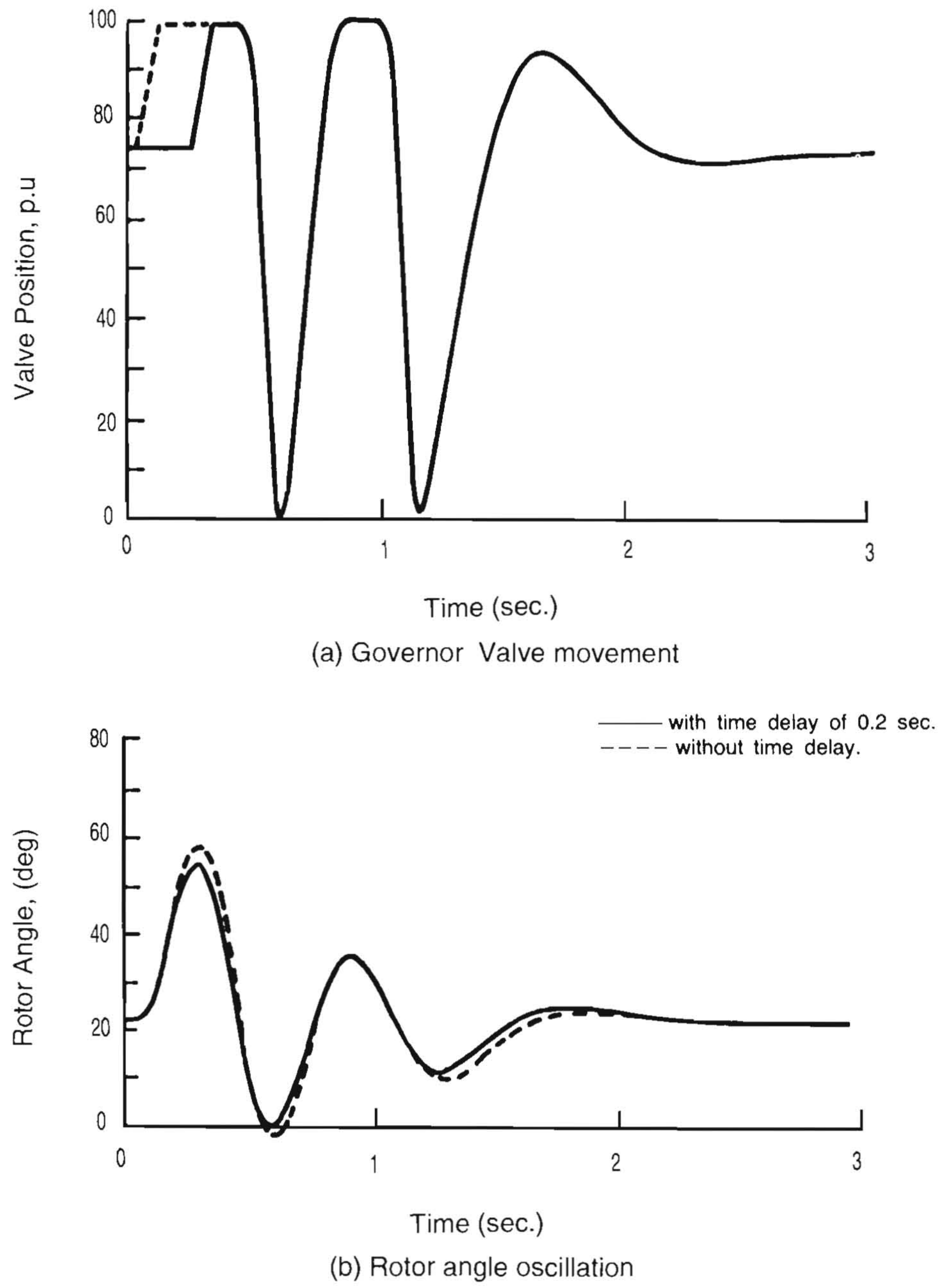


Fig. 7. Controlled System performance at P = 0.7 & Q = 0.5 p.u.

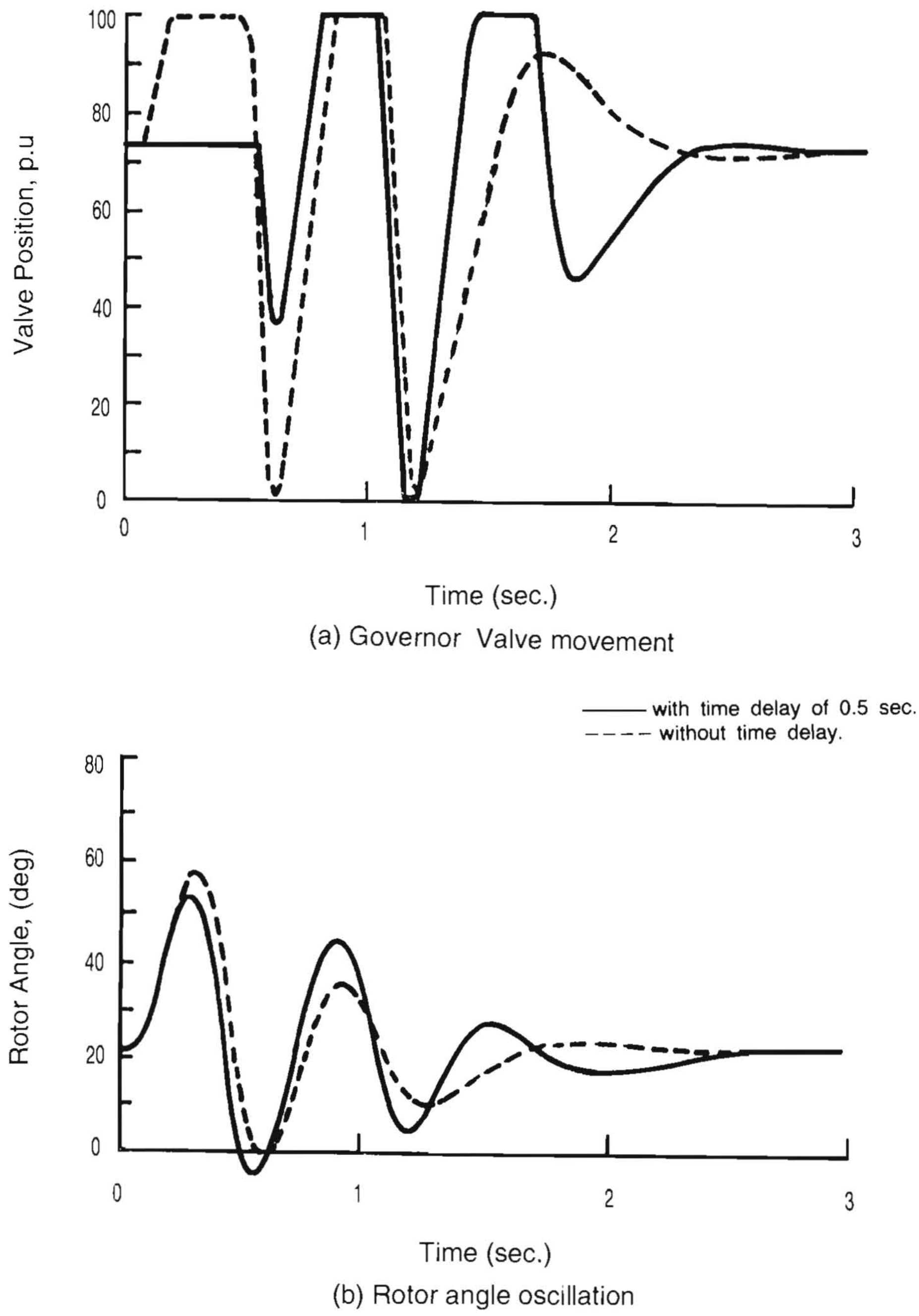


Fig. 8. Controlled System performance at P = 0.7 & Q = 0.5 p.u.

Conclusions

From the foregoing discussion it can be concluded that:

1. Large superconducting generators, turbine and transmission system forms completely controllable system.
2. The post fault oscillations of the rotor can be effectively damped out by employing a pole-placement state-space feedback controller in conjunction with a fast acting electrohydraulic governor.
3. The first swing of the rotor angle can be effectively curtailed by incorporating a time delay to the controller to the governor servomechanism.

Thus the prime mover control by a pole-placement state feedback controller enhances overall transient stability of the superconducting generator by rapid damping of the oscillations and curtailing the first swing of the rotor angle.

Appendix

Transient model of the alternator

The transient model of the superconducting alternator is represented by the following equations;

$$p\delta = w \qquad (15)$$

$$pw = w_o(T_m - T_e)/2H \qquad (16)$$

$$p\psi f = w_o(V_f - R_f i_f) \qquad (17)$$

$$p\psi_d = w_o(V_d + \psi_q + (R_a + R_e)i_d) + w\psi_q \qquad (18)$$

$$p\psi_{D1} = -w_o R_{D1} i_{D1} \qquad (19)$$

$$p\psi_{D2} = -w_o R_{D2} i_{D2} \qquad (20)$$

$$p\psi_q = w_o(V_q - \psi_d + (R_a + R_e)i_q) - w\psi_d \qquad (21)$$

$$p\psi_{Q1} = - w_o R_{Q1} i_{Q1} \qquad (22)$$

$$p\psi_{Q2} = w_o R_{Q2} i_{Q2} \qquad (23)$$

Linearized model of the system

According to the simplifying assumptions given before, the generator equations are reduced to the following;

$$V_d = - \psi_q \qquad (24)$$

$$V_d = \psi_d \qquad (25)$$

$$p\psi_{D2} = -w_o R_{D2} i_{D2} \qquad (26)$$

$$p\psi_{Q2} = -woR_{Q2} i_{Q2} \qquad (27)$$

$$p\psi_f = w_o(V_f - R_f i_f) = 0 \qquad (28)$$

The terminal voltage and current are given by;

$$V_t^2 = V_d^2 + V_q^2 \qquad (29)$$

$$i_t^2 = i_d^2 + i_q^2 \qquad (30)$$

The transmission system is represented by;

$$V_d t = V_b \text{ sing } \delta - X_e i_q \quad \text{.......} (31)$$

$$V_{qt} = V_b \text{ Cos } \delta + X_e i_d \quad \text{.......} (32)$$

The change in the d-axis flux can be written in the following form;

$$p[\psi] = [L]p[i] \quad \text{.......} (33)$$

where;

$$[\psi] = \begin{bmatrix} \psi_d \\ \psi_{D2} \\ \psi_f \end{bmatrix} = \begin{bmatrix} -X_d & X_{dD2} & X_{dF} \\ -X_{dD2} & X_{D2} & X_{FD2} \\ -X_{dF} & X_{FD2} & X_f \end{bmatrix} \cdot \begin{bmatrix} i_d \\ i_{D2} \\ i_f \end{bmatrix} \quad \text{.....} (34)$$

Using the assumption of constant flux linkage of the field winding, the row and column associated with the field winding may be eliminated by using simple matrix reduction. The result of this reduction gives;

$$\begin{bmatrix} \psi_d \\ \psi_{d2} \end{bmatrix} = \begin{bmatrix} -X'_D & X_{adM} \\ X_{adM} & X_{D2M} \end{bmatrix} \cdot \begin{bmatrix} i_d \\ i_{D2} \end{bmatrix} \quad \text{.......} (35)$$

The linearized model of the generator and turbine reduces to the following;

$$\begin{bmatrix} p\Delta\delta \\ p\Delta w \\ p\Delta\psi_{D2} \\ p\Delta\psi_{Q2} \\ P\Delta G_v \\ P\Delta T_m \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ A_7 & 0 & A_8 & A_9 & 0 & w_o/2H \\ A_{10} & 0 & -A_4 & 0 & 0 & 0 \\ A_{11} & 0 & 0 & -A_6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1/T_G & 0 \\ 0 & 0 & 0 & 0 & K_T/T_T & 1/T_T \end{bmatrix} \cdot \begin{bmatrix} \Delta\delta \\ \Delta w \\ \Delta\psi_{D2} \\ \Delta\psi_{Q2} \\ \Delta G_v \\ \Delta T_m \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1/T_G \\ 0 \end{bmatrix} (\Delta U_g) \quad \text{....} (36)$$

where;

$$A_1 = \frac{X_{adM}}{D} \qquad A_2 = \frac{X_{aq}}{Q}$$

$$A_3 = \frac{{}_{wo}R_{D2}X_{adm}V_b}{D} \qquad A_4 = \frac{{}_{wo}R_{D2}X'_d}{D}$$

$$A_5 = \frac{{}_{wo}R_{Q2}X_{aq}V_b}{Q} \qquad A_6 = \frac{{}_{wo}R_{q2}X_q}{Q}$$

$$A_7 = (A_2X_4 \sin X_1 - A_1X_3 \cos X_1) \frac{w_o}{2H}$$

$$A_8 = \frac{w_o}{2H} A_1 \sin X_1 \qquad A_9 = -\frac{w_o}{2H} A_2 \cos X_1$$

$$A_{10} = -A_3 \sin X_1 \qquad A_{11} = -A_5 \cos X_1$$

$$X'_d = X_1 + X_{adM} \qquad X_{adM} = \frac{X_{ad}X_f}{X_{ad} + X_f}$$

$$D = X'_d X_{D2M} - X^2_{adM} \qquad Q = X_d X_{D2} - X^2_{adM}$$

$$X''_1 = X_d - \frac{X^2_{adm}}{X_{D2M}}$$

$$X_{D2M} = X_{D2l} + X_{adM}$$

The transformation from the unmeasurable quantities in (Keim and Loskoris 1985) to the measurable quantities of (Alyan and Rahim 1988) is done according to the following;

$$\begin{bmatrix} \Delta\delta \\ \Delta w \\ \Delta V^t \\ \Delta I^t \\ \Delta G_v \\ P\Delta T_m \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ A_{12} & 0 & A_{13} & A_{14} & 0 & 0 \\ A_{15} & 0 & A_{16} & A_{17} & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \Delta\delta \\ \Delta w \\ \Delta\psi_{D2} \\ \Delta\psi_{Q2} \\ \Delta G_v \\ \Delta T_m \end{bmatrix} \quad \text{...............(37)}$$

Where;

$$A_{12} = \frac{V_b}{V_t}\left[\frac{X''_d}{X''_d + X_e} V_{td} \cos\delta - \left(1 - \frac{X_e X_{D2M}}{D}\right) V_{tq} \sin\delta\right]$$

$$A_{13} = \frac{X_e X_{adM} V_{qt}}{DV_t}$$

$$A_{14} = -\frac{X_e X_{qQ2} V_{dt}}{QV_2}$$

$$A_{15} = \frac{V_b}{I_t}\left[\frac{I_d X_{D2M}}{D} \sin\delta + \frac{I_q X_{Q2}}{Q} \cos\delta\right]$$

$$A_{16} = \frac{I_d X_{adM}}{I_t D}$$

$$A_{17} = \frac{I_q X_{qQ2}}{I_t Q}$$

List of Main Symbols

V	= voltage (pu)
I	= current (pu)
X	= reactance (pu)
R	= resistance (pu)
ψ	= fluxlinkage (pu)
Γ	= time constant (sec)
T_m	= mechanical torque (pu)
G	= valve position (pu)
δ	= load angle (radians)
$w_\circ$	= rated angular frequency (radians/sec)

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(Received 22/12/1992);
in revised form 20/06/1993)

تحسين حالة إستقرار المولدات فائقة التوصيل عن طريق تخصيص الأقطاب

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بعد تطور المواد الفائقة التوصيل والتي بإمكانها ان تحمل تيارا كهربائيا عالي القيمة دون حدوث أي فقدان في الطاقة الكهربائية، اتجهت أنظار الباحثين في كافة أرجاء العالم باهتمام كبير إلى تطوير المولدات التوربينية للتيار المتناوب بلفائف مجال مغناطيسي من مواد فائقة التوصيل. وقد ساد الاتجاه نحو بناء وتطوير المولدات التوربينية الضخمة بحيث تستخدم المواد فائقة التوصيل في ملفات الحث المغناطيسي والتي تكون قادرة على انتاج مجال مغناطيسي قوي جدا يقوم بدوره بتوليد جهود كهربائية عالية وطاقة كهربائية ضخمة، لذا يلزم بناء تلك المولدات التوربينية فائقة التوصيل بقلب هوائي خالي من الحديد أي باستخدام مواد غير مغناطيسية داخل عضوها الدوار مما يجعلها خفيفة الوزن نسبيا وذات فعالية أكبر وحجم أصغر وكفاءة أعلى اذا ما قورنت بمثيلاتها من ذات البناء التقليدي. وهذا يؤدي بالطبع الى خفض سعرها الابتدائي ووزنها وكذلك خفض تكاليف التشغيل والصيانة.

من أهم النواحي التي يجب مراعاتها عند تصميم هذه المولدات هي عودتها السريعة الى حالة الاستقرار بعد أي اضطراب يحدث في الشبكة الكهربائية

المتصلة بها لأن خفة وزن عضوها الدوار والترابط المغناطيسي الضعيف بين عضوها الساكن وعضوها الدوار والناتج عن القلب الهوائي يجعلان هذه المولدات عرضة للجنوح مما يؤثر على استقرارها بعد اضطراب الشبكة الكهربائية .

ان التحكم في المولدات التوربينية التقليدية يتم بالتنسيق بين مجهود كل من ملفات الحث المغناطيسي والصمامات البخارية والتي قد تبين انها تقوم بتحسين استقرار المولدات التقليدية بشكل فعال، إلا ان مجهودات ملفات الحث المغناطيسي تكون غير فعالة في حالة المولدات فائقة التوصيل نسبة لكبر ثابتها الزمني فبالتالي يتم الاعتماد بالكامل على مجهودات التحكم في الصمامات البخارية .

وقد تم البحث عن امكانية تصميم نظام تحكم ذو تغذية عكسية يصمم على أساس مبدأ تخصيص الاقطاب لمعادلة الخواص للنظام المقترح . لاجراء هذه الدراسة تم افتراض وجود نظام مكون من مولد توربيني فائق التوصيل مزدوج التغليب يدار بواسطة توربينات بخارية ثلاثية المراحل وموصل بشبكة كهربائية كبيرة من خلال محول وخط نقل للقدرة، وعليه تم تمثيل النظام المقترح بمجموعة مكونة من ١٥ معادلة تفاضلية غير خطية يتم حلها بطريقة التكامل العددي باستخدام الحاسب الآلي. بعد ذلك تم تحويل المعادلات غير الخطية الى معادلات خطية وتخفيضها الى ٦ معادلات فقط وذلك بتبسيط النظام إذ يساعد ذلك على تصميم نظام التحكم بصورة أيسر وأكثر فعالية .

تم شرح طريقة تصميم نظام التحكم بالتغذية الخلفية المقترح باسلوب تحديد مكان أقطاب معادلة الخواص ومن ثم اختبار نظام التحكم بعد تمثيل النظام المستخدم بالحاسب الآلي مع افتراض وجود قصور في خط نقل القدرة ثم استعراض النتائج عند جميع نقاط العمل المحتملة للمولد .

أثبتت النتائج ان نظام التحكم المقترح يعتبر فعالا جدا في اخماد الاهتزاز في العنصر الدوار للمولدات فائقة التوصيـل المدارة بـواسطة تـوربين بخـاري مزود بصمامات الكتروهيدروليكية سريعة الاستجابة.