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Decentralized Proportional-Plus-Integral Design Method for Two Area Interconnected Power Systems

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Abstract: **A simple and computationally efficient de-centralized control design method is given for load frequency control in the interconnected power systems. This de-centralized scheme comprises of a reduced order observer and a proportional plus integral controller in each area of the power system. It ensures zero static change in area-frequency and tie-line power. Some of the features of the de-centralized scheme are de-centralized implementation of a wide choice of feedback controllers, which have been designed off-line to meet the requirement of the global system and there is no need for inter-area transfer of data, for the purpose of load frequency control. The de-centralized controls are tested on computer-base simulation of two area interconnected power system. The simulated responses show that the de-centralized control scheme gives the satisfactory performance similar to centralized control scheme.**

Index Terms— **AGC- Automatic Generation Control, TAIPS-Two area Interconnected power system, PI controller-Proportional Integral controller**

I. INTRODUCTION

Now a day's large electric power system are highly interconnected to satisfy the two cardinal objectives of the power system operation, namely, the continuity of service and the economy of power generation. The major requirement in the parallel operation of several interconnected systems is the control of frequency and inter-area tie line power flow. In the normal mode of operation of an interconnected power system, the governor control loop (primary control loop) senses the frequency deviation and a corrective action takes place to eliminate the mismatch between the generated and the demand power. However, due to the inherent droop characteristics of the speed governors, there still persists a finite amount of frequency deviation which can be eliminated by a second level control known as 'Load Frequency Control' (LFC) or 'Automatic Generation Control' (AGC)

1.1 INTERCONNECTED POWER SYSTEM

The load frequency control of a large interconnected power system has been studied by dividing the whole system into a number of control areas.

1.2. DECENTRALIZED CONTROL SCHEME

The main motivation behind the Decentralized control is the failure of conventional method of centralized control theory. Some fundamental techniques such as pole placement, state feedback, optimal control, state estimation, of the centralized control theory requires complete information from all system sensors for the sake of feedback control. This centralized scheme is clearly inadequate for the feedback control of large scale system.

The basic idea of Decentralized control scheme X_1 is used to find out the vector u_1, while X_2 alone is used to find out u_2.

Thus, $X = (X_1\ X_2)^T$

$u_1 = -k_1 X_1$ &

$u_2 = -k_2 X_2$

It means the control signals of both the areas, Viz. u_1 and u_2 are determined separately and fed back to the system. Thus this method is more economical than centralized control scheme because of cost saving in data communication channel

II. PROBLEM FORMULATION

Given a Two area interconnected power system. design a Decentralized optimal PI-controller and Decentralized reduced order observer for each of the system so that the closed loop system is stable and so that the system frequency and tie-line power flow are regulated to their given set point; when the system is subjected to any constant input disturbances which may be occur in the system due to load fluctuations.

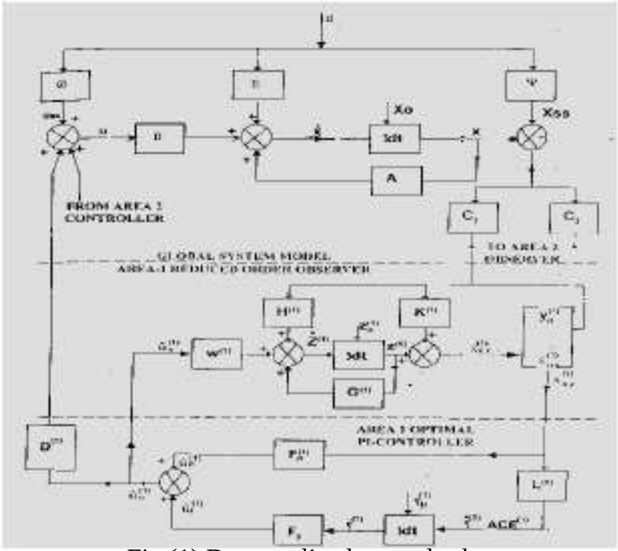

Fig (1) Decentralized control scheme

An example of this type of problem is given in figure (1). In this figure the Decentralized closed loop system for area-1 is shown. It is divided into main three parts viz. global system model, area-1 reduced order observer, area-1 optimal PI-controller. Here the term 'Global System' is used for the overall system consisting of both areas-1 and areas-2.

III. CASE STUDY

This method of Decentralized control is applied to a problem of two area interconnected power system. First, the state space representation for a TAIPS is obtained.

$x_n(t) = Ax_n(t) + Bu_n(t)$

with initial conditions,

$x_n(0) = - x_{ss}$,

$u_n(0) = - u_{ss}$,

It is then followed by the design of optimal PI-controller and reduced order observer. Then the overall closed loop system matrix is calculated and its eigen values are computed in order to check the stability of the whole system.

$\square^*(t) = A_c \, \square(t)$

Finally the response of incremental tie line power (ΔP_{tie}) area-1 (ΔF_1) and area-2 (ΔF_2) are determined for Decentralized control method. The response of the same variables but using centralized control method. The response of the same variables but using centralized control is also determined for the purpose of comparison and is shown in fig 2,3,4.

In order to study this Decentralized control method, the following data is assumed

Rated power $P_{rated1} = P_{rated2} = 2000$MW

Nominal frequency $f^* = 50$ Hz

Inertia constant $H_1 = H_2 = 5$s

Load frequency constants

$= D1 = D_2 = 0.00833$ p.u. MW/Hz

Turbine time constant $T_{t1} = T_{t2} = 0.3$s.

Speed governor time constants

$= Tg1 = T_{g2} = 0.08$s.

Regulation constant $R_1 = R_2 = 3$ Hz/Pu MW

Maximum tie line power $P_{tie,\,max} = 200$ MW

Difference in area power angles

$= \delta^*_1 - \delta^*_2 = 20^0$

Synchronizing coefficient

$T_{t2} = 2\pi \cos(\delta^*_1 - \delta^*_2) \, P_{tie,\,max} = 0.590$ PuMW

P_{rated}

Change in load demand for area - 1

$\Delta P_{d1} = 0.01$ puMW

Change in load demand for area - 2

$\Delta P_{d2} = 0$

Frequency bias constant $B_{f1} = B_{f2} = 0.425$

For this study, all the computer programs are written using PRO-MATLAB software and for determination of responses following steps have been followed.

a) State-space representation for a two area interconnected power system -

b) Design of PI-controller -

1. Calculation of error matrix L
2. Weighting matrices Q and R
3. Calculation of Fp and F_I in global optimal feedback control
4. Calculation of Fp $^{(i)}$ and F_I in area feedback control

c) Design of area based reduced order observer -

d) Calculation of the overall closed loop system matrix -

e) Determination of $\Delta P_{tie\,1\,2}$ responses.

1) CENTRALIZED METHOD

The offset system state equation is

$x^*_n(t) = Ax_n(t) + Bu_n(t)$

In case of centralized scheme the control inputs is given by

$u_n(t) = -Kx_n(t)$

Where K is the optimal feedback gain matrix Determination of the feedback matrix K which minimizes the performance index.

P –

Is the standard optimal regulator problem K is obtained from solution of the reduced matrix Riccati equation given below

$A^T P + PA - PBR^{-1} B^T P - Q = 0$

$K = R^{-1} B^T P$

Where Q is constant position semi definite, symmetric matrix for system states and R is constant position definite symmetric matrix for controls. The acceptable solution of K is that for which the system remains stable Substituting this K in equation the system dynamics with feedback is defined by

.

$X_n = (A - BK) X_n$

For stability all the eigen values of the matrix (A-BK) should have negative real parts. The homogeneous state equation is solved by using the same method as described for Decentralized scheme.

A computer program is written which when given the matrices A, B, Q, R computes the solution P of matrix Riccati equation and the optimal feedback gain matrix K. It then calculates the closed loop system matrix $A_c = A - BK$ the eigen values of Ac are calculated to check the stability of the system. As all these eigen values are having negative real parts, it indicates that the system is stable. The incremental tie line power, area-1 frequency and area-2 frequency responses for both Decentralized and centralized control schemes are plotted on the graph for the purpose of comparison.

2) DECENTRALIZED METHOD

The Decentralized controller designed for a TAIPS is tested in a response study where a one percent step increase in the load demand in area-1 is considered, with no change to the load demand in area-2. The solution of the homogeneous state equation

$□^{*}(t) = A_c □(t)$

is obtained by using e^{At} method and it is given by

$□(t) = e^{At} □(0)$

Where

$□(0) = □_1$ = initial conditions vector

The initial condition vector for offset system is given as $x_n^{(0)} = -x_n$.

At steady state conditions $□P_{tie}$, $□f_1$, $□f_2$ are all zeros while $□P_{g1} = □P_{d1} = 0.01$ pu and $□x_{g1} = 0.01$ pu is considered. Also as no load change in area-2 is considered, $□P_{g2} = □x_{gv2} = 0.0$

The initial conditions for controllers and observers are all taken as zeros.

A computer program is written, which, when given the overall system matrix, A_c, computes the solution of state equation it then plots the incremental tie line power, area-1 frequency and area-2 frequency responses which are plotted in fig 2,3,4

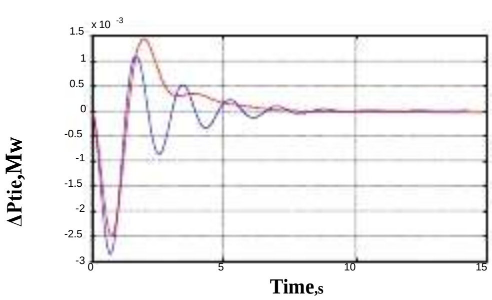

Fig 2 –Tie-line power responses
1%step increase in load demand in Area1

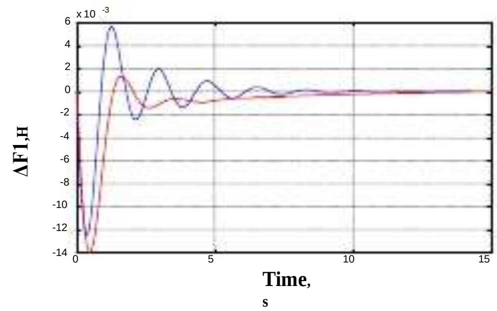

Fig 3- F1 Response(1%step increase in load demand in Area 1)

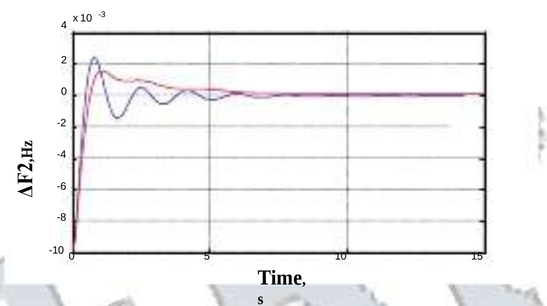

Fig 4- F2 Response(1%step increase in load demand in Area 1)

(In Fig . Blue line—Decentralised ,Red line –Centralised)

CONCLUSION

A two area interconnected power system (TAIPS) has been considered in this dissertation. The megawatt-frequency control problem has been considered separate from the megavar-voltage control problem for two reasons; one reason is that, for small changes in system load, system voltage remains fairly constant while frequency deviates. The second reason is that, the megavar-voltage control problem has much faster response than the megawatt-frequency control problem. Therefore, a new method of fully de-centralized feedback control for load frequency control and tie-line power control of two area interconnected power system is studied in the present dissertation. This de-centralized control scheme comprises of a reduced order observer and PI-controller for each area. Each area controller utilizes output feedback from a set of measurements containing the total area power generation and the inter-area tie-line power. The reduced order observer for each area uses area measurements in order to reconstruct the global system state vector within each area. Area feedback controllers are obtained from a simple partitioning of a globally designed system matrix. The PI-controller is included in the general design to ensure zero static error in the system frequency and scheduled tie-line power.

The de-centralized controller designed for a TAIPS is tested in a simulation study considering a step load disturbance of 0.01 p.u. in area-1 with no load change in area-2. The ΔP_{tie}, $\Delta F_1$and ΔF_2 responses are obtained for both, de-centralized and centralized control. It is observed that the simulated system responds more slowly, with greater overshoot, in the case of de-centralized control. This is because of the presence of the observers in the de-centralized scheme, and arises from the time taken for the area observers to settle following a load demand change.

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