Dynamic Analysis And Stability Of The Load Frequency Control In Two Area Power System With Steam Turbine

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Abstract

In this paper a new robust load frequency controller for two area interconnected power system is presented to quench the deviations in frequency and tie line power due to different load disturbances. The dynamic model of the interconnected power system is developed with the integral control. Basic dynamic model representation of a two area power system given in the reference [2] is considered and the responses of two area power systems are evaluated. The so called Load Frequency Control Problem is restructured as a state transfer problem and using a suitable control strategy the system should be transferred from an initial state to the final state without any oscillations (if possible) in frequency deviations and tie line power deviations and thereby the time to reach final steady state is very much reduced. The MATLAB/Simulink based simulations are provided and the results in terms of different constants like inertia constant, integration constant, and the turbine constant are studied.

Keywords: load frequency control; dynamic analysis; integral controller.

Introduction

Modern day power systems are divided into various areas. For example in India , there are five regional grids, e.g., Eastern Region, Western Region etc. Each of these areas is generally interconnected to its neighboring areas. The transmission lines that connect an area to its neighboring area are called **tie-lines** . Power sharing between two areas occurs through these tie-lines. Load frequency control, as the name signifies, regulates the power flow between different areas while holding the frequency constant. The power system frequency rises when the load decreases if ΔP_{ref} is kept at zero. Similarly the frequency may drop if the load increases. However it is desirable to maintain the frequency constant such that $\Delta f=0$. The power flow through different tie-lines are scheduled - for example, area- i may export a pre-specified amount of power to area- j while importing another pre-specified amount of power from area- k . However it is expected that to fulfill this obligation, area- i absorbs its own load change, i.e., increase generation to supply extra load in the area or decrease generation when the load demand in the area has reduced. While doing this area- i must however maintain its obligation to areas j and k as far as importing and exporting power is concerned. A conceptual diagram of the interconnected areas is shown in figure. For large scale power systems which consists of inter-connected control areas, load frequency then it is important to keep the frequency and inter area tie power near to the scheduled values. The input mechanical power is used to control the frequency of the generators and the change in the frequency and tie-line power are sensed, which is a measure of the change in rotor angle. A well designed power system should be able to provide the acceptable levels of power quality by keeping the frequency and voltage magnitude within tolerable limits. Changes in the power system load affects mainly the system frequency, while the reactive power is less sensitive to changes in frequency and is mainly dependent on fluctuations of voltage magnitude. So the control of the real and reactive power in the power system is dealt separately. The load frequency control mainly deals with the control of the system frequency and real power whereas the automatic Voltage regulator loop regulates the changes in the reactive power and voltage magnitude. Load frequency control is the basis of many advanced concepts of the large scale control of the power system.

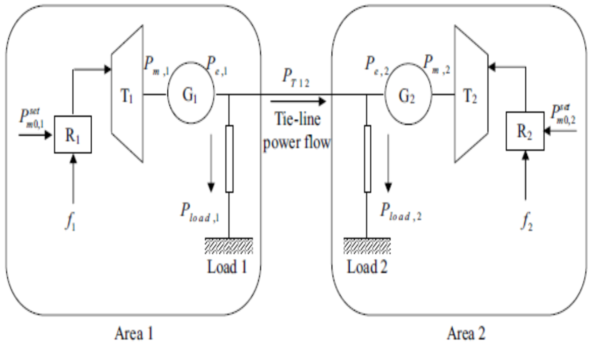
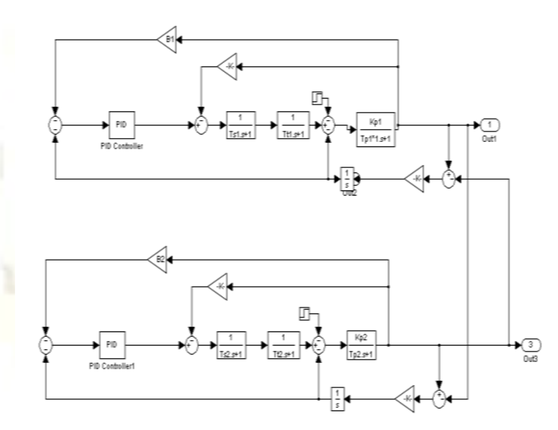


Fig 1: Interconnected areas in a power system

II Dynamic Studies

In this section, an analytical approach is given for the investigation of two area power system

dynamics. The LFC system consists of four parts: turbine, governor, electrical system and controller. A block diagram representation for the two area system with LFC containing integral controller is shown in Fig. 2, where GT(s), GG(s) and GP(s) denote the transfer functions of turbine, governor and electrical systems respectively. Changes in load are accompanied by changes in system frequency, generation and tie line power flows. The system frequency and tie line power flows must be kept within specified limits. The inputs to the system are
Changes to the electric load ΔPD1 and ΔPD2 in each area. Quantities of interest are the mechanical power output of the turbine, ΔPT1 and ΔPT2, changes to the plant set point, PC1 and PC2, output change of governor, ΔPG1 and ΔPG2, and the system frequency increment, ΔPF1 and ΔPF2, of the each area system. Other quantity of interest is the deviation of tie line power flow out of the area from the scheduled power flow, ΔPTIE. It is known that LFC systems include an integral control as secondary controller, in conventional control configurations.



In practice the adjustment of ΔPC1 and ΔPC2 is done automatically by the tie line bias control or secondary control. Each area supplies its user pool and allows electric power to flow between areas. The control error for each area consists of a linear combination of frequency error and tie-line error [9]. The area control error (ACE) must be kept close to zero in each control area. The ACE is used as the input of the PI controller of LFC, while the output is the raise/lower signal (ΔPC) sent to generating units to adjust their generated power to meet the demand [14]. The ACE for a two area system is:

$$ACE_N = (-1)^{N+1}\Delta P_{TIE} + B_N \Delta f_N \qquad N=1,2$$

where N is number of area and BN is frequency bias setting. The BN should be high enough such that each area adequately contributes to frequency control. The choosing BN equal to the area frequency response characteristic (β), gives satisfactory performance of interconnected system. The value of β varies according to electric load characteristic, governor performance and speed regulation settings [15]. If speed regulation factor and damping factor system for an each area is represented by RN and DN respectively, then the β_N is:

$$\beta_N = D_N + \frac{1}{R_N}$$

The value of ΔfN in (1) represents the amount of frequency variation, which can be calculated as below:

$$\Delta f_N = f - f_o$$

where fo is the nominal frequency and f is the operating frequency. The frequency bias BN determines the amount of interaction during a disturbance in the neighboring areas. The BN should be high enough such that each area adequately contributes to frequency control. The ACEs are used as actuating signals to activate changes in the reference power set points, and when steady state is reached, ΔPTIE and ΔfN is returned to zero and ACE1=ACE2. Sate equation
of two area system with controller and without reheat with
nine variables:

$$X = [\Delta f_1\ \Delta P_{T1}\ \Delta P_{G1}\ \Delta P_{C1}\ \Delta P_{TIE}\ \Delta f_2\ \Delta P_{T1}\ \Delta P_{G1}\ \Delta P_{C1}]^T$$

$$U = [\Delta P_{D1} \quad \Delta P_{D2}]^T$$

are obtained. The equation systems for N=1, 2 are:

$$\frac{d}{dt}\Delta P_{GN} = -\frac{1}{T_{GN}}\Delta P_{GN} + \frac{K_{GN}}{T_{GN}}\Delta P_{CN} + \frac{K_{GN}}{T_{GN}R_N}\Delta f_N$$

$$\frac{d}{dt}\Delta f_N = -\frac{1}{T_{PN}}\Delta f_N + (-1)^N\frac{K_{PN}}{T_{PN}}\Delta P_{TIE} - \frac{K_{PN}}{T_{PN}}\Delta P_{DN} + \frac{K_{PN}}{T_{PN}}\Delta P_{TN}$$

$$\frac{d}{dt}\Delta P_{TN} = -\frac{1}{T_{TN}}\Delta P_{TN} + \frac{K_{TN}}{T_{TN}}\Delta P_{GN}$$

$$\frac{d}{dt}\Delta P_{CN} = -K_{IN}B_N\Delta f_N + (-1)^N K_{IN}\Delta P_{TIE}$$

III MATLAB/SIMULINK MODELING AND SIMULATION RESULTS

The below figure shows the MATLAB/SIMULINK circuit of the two area power system.

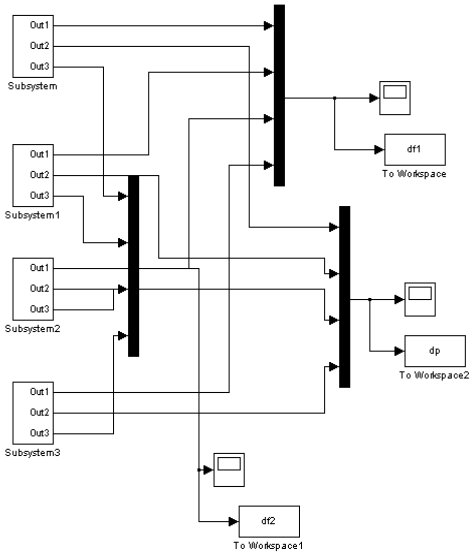


Fig 3: MATLAB/SIMULINK circuit of the two area power system.

The below figure shows the output waveforms of the system which shows the Frequency deviation in terms of integration constant changes of first area

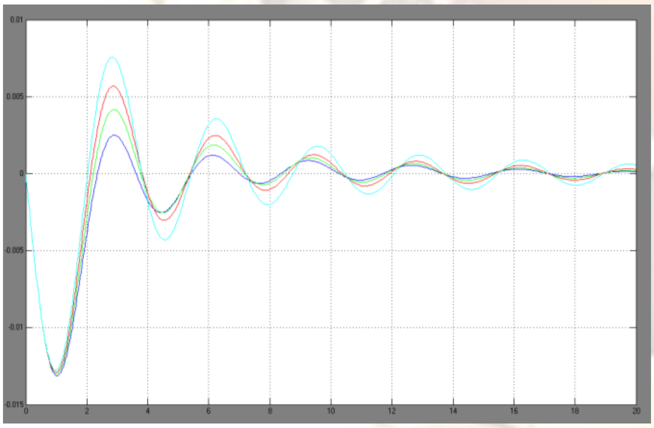


Fig 4: Frequency deviation in terms of integration constant changes of first area

The below figure shows the output waveforms of the system which shows the Frequency deviation in terms of integration constant changes of second area

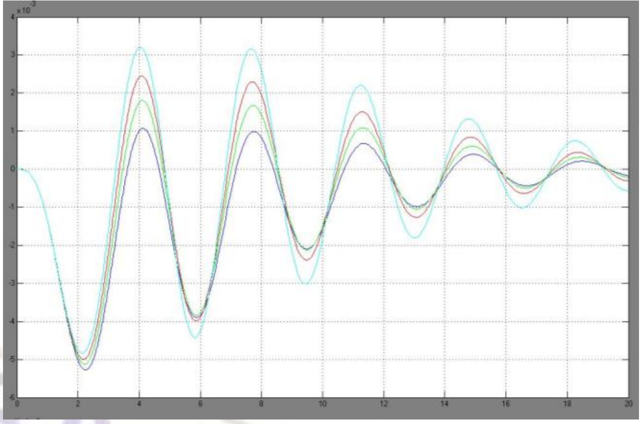


Fig5: Frequency deviation in terms of integration constant changes of first area

The below figure shows the output waveforms of the system which shows the Frequency deviation in terms of turbine time constant changes of first area

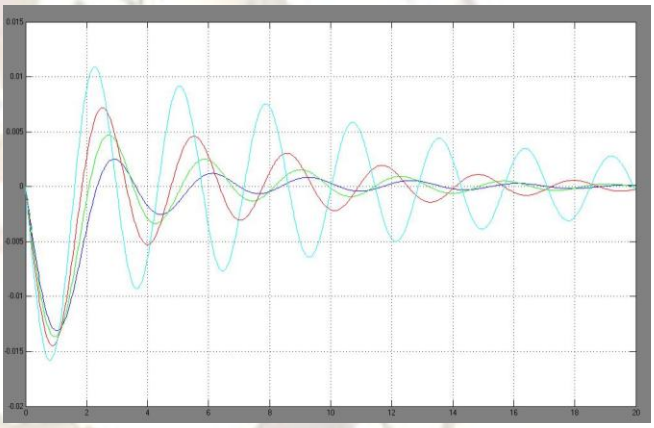


Fig 6: Frequency deviation in terms of turbine time constant of first Area

The below figure shows the output waveforms of the system which shows the Tie line power flow deviation in terms of inertia constant changes of first area

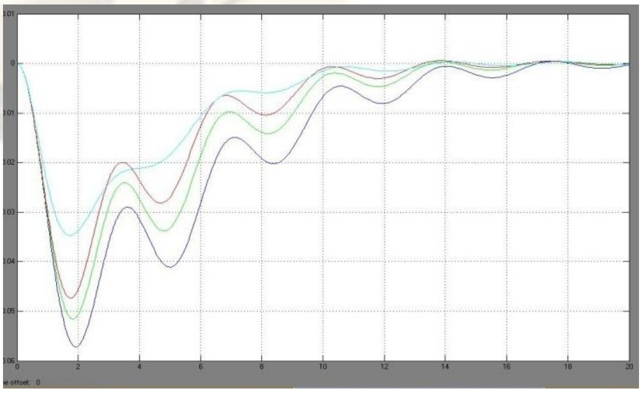


Fig 7:Tie line power flow deviation in terms of inertia constant changes of first area

The below figure shows the output waveforms of the system which shows Tie line power flow deviation in terms of integration constant changes of first area

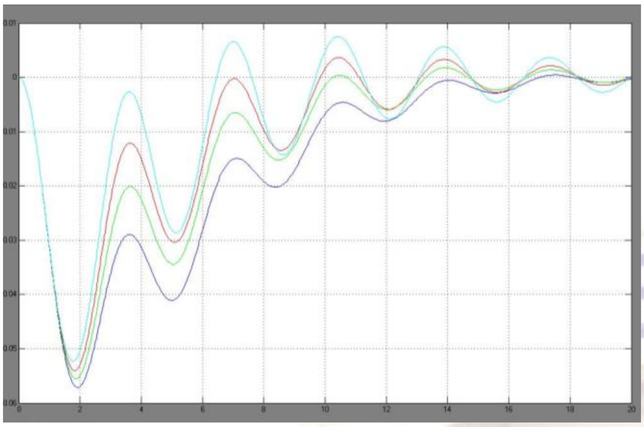


Fig 8: Tie line power flow deviation in terms of integration constant changes of first area

The below figure shows the output waveforms of the system which shows Tie line power flow deviation in terms of turbine time constant of first area

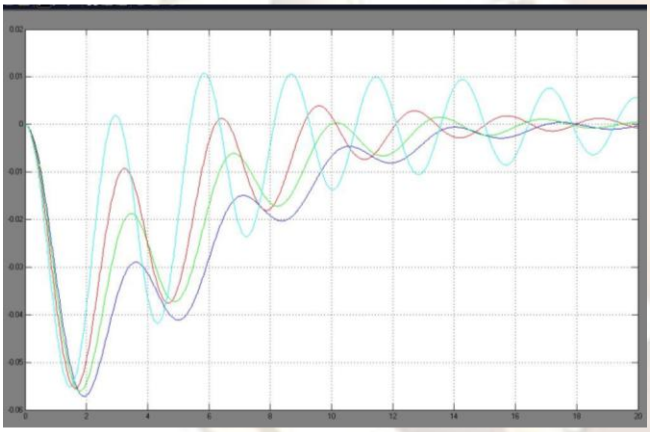


Fig 9:Tie line power flow deviation in terms of turbine time constant
of first area

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