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Automatic Load Frequency Control of Two Area Power System Using Proportional Integral Derivative Tuning Through Internal Model Control

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Abstract: *The main purpose of operating Load Frequency Control (LFC) is to keep uniformly the frequency changes during the load changes. In this paper, Automatic Load Frequency control of two area power systems using Proportional Integral Derivative (PID) tuning through internal model control (IMC) technique. Two main objectives of LFC are to maintain the real frequency and the desired power output in the interconnected power system and, to control the change in tie line power between control areas. The PID-IMC controller have the ability to provide high adaption for changing conditions and the ability for making quick decisions. The controller are used to improve the dynamic response as well as to reduce or eliminate the steady-state error. It is much faster, applicable under different nonlinearities and give better stability response as compared to the conventional integral Load Frequency controllers for a two area power system.*
Keywords: *Proportional Integral Derivative, Load Frequency Control, internal model control, Tie-line, Twoarea power systemso*

I. Introduction

The main purpose of operating the load frequency control is to keep uniformly the frequency changes during the load changes. During the power system operation rotor angle, frequency and active power are the main parameters to change [1]. The interconnection of more than one control areas through tie lines is call power systems. Generating plants in a control area always vary their speed together for maintenance of frequency and the relative power angles to the predefined values in both static and dynamic conditions. When there is any sudden load change occurs in a control area of an interconnected power system there will be frequency deviation as well as tie line power deviation. Two main objective of Load Frequency Control (LFC) are, to maintain the real frequency and the desired power output in the interconnected power system and, to control the change in tie line power between control areas [2]. When there is a small change in load power in a single area power system operating at set value of frequency it creates mismatch in power both for generation and demand. Nowadays there are more complex power systems which required operation in less structured and uncertain environment. Similarly innovative and improved control is required for economic, secure and stable operation. The conventional Proportional Integral (PI) controller [3,4] has the following drawback a) Inherent nonlinearity of different power system components; b) There is continuous load changes occurrence during daily cycle, this changes the operating point accordingly and c) very slow in operation [5]. In this paper, a proposed advance control techniques having the ability to provide high adaption for changing conditions and the ability for making quick decisions is the Proportional Integral Derivative (PID) controller. The PID controller is used to improve the dynamic response as well as to reduce or eliminate the steady-state error [6]

Two Area Power Systems

A two area system consists of two single area systems, connected through a power line called tie-line. Figure 1 shows a two area power system where each area supplies to its own area and the power flow between the areas are allowed by the tie line. For two area power system, the individual areas are strong, the tie line which connects the two area is weak and a single frequency is characterized throughout. A block diagram model of two area power system with integral controller is shown in Figure 2. The block diagram model contained two control inputs named u1 and u2. The block diagram representing a two area power system model is having two control areas connected to each other through a line having its own dynamics (block 7) called tie line. From the figure it is clearly seen that the control areas are made-up with three block each with an integral controller block. The three blocks are namely governor block, turbine block, and the power system block which is actually the load block.

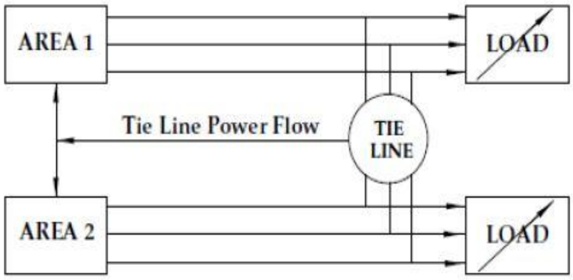

Figure1: Two area interconnected power system

Model of a Two Area Thermal Non-Reheat Power System

Both areas consist of four blocks each and another one block represents the tie line power. Therefore total 9 blocks are present for the whole system [7,8].

The control input equations can be written as below:

For area 1 (at block 8)

$$u_1 = -K_T(ACE_1) = -K_T(B_1x_1 + x_7) \quad (1)$$

For area 2 (at block 9)

$$u_2 = -K_T(ACE_2) = -K_T(B_2x_4 - x_7) \quad (2)$$

Where ACE1 and ACE2 are the Area Control Errors of area-1 and area-2 respectively. KT is the integral gain for both the areas.

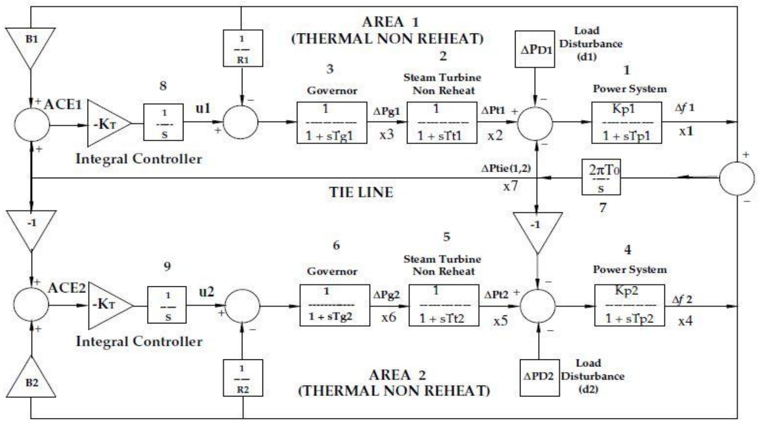

Figure 2: Two area thermal (non-reheat) power system with integral controller

II. Materials And Methods

Tuning of PID controllers proposed for LFC via Internal model control (IMC) considering the simplicity of their execution [8,9,10,11] in load frequency controller PID tuning method for two area power system.

A. Design of Internal model control (IMC)

An internal model control (IMC) method is adapted for load frequency controller design. In Process control IMC is a very popular controller [7]. Figure 3 show the IMC structure where the plant to be controlled is 'P', and the plant model is 'Ṗ'.

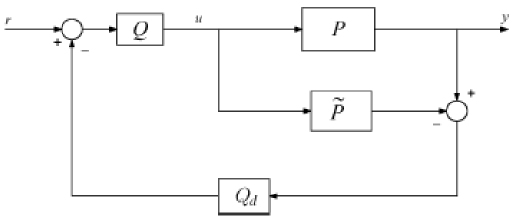

Figure 3: IMC structure

IMC design procedure is given in equation 3 as

$$\dot{P}(s) = P_M(s)\, P_A(s) \quad (3)$$

Where P_M (s) invertible minimum phase in part, and P_A (s) is the no minimum phase part with unity magnitude.

Design an IMC controller

$$Q(s) = P_M^{-1}(s)\frac{1}{(\lambda s+1)^r} \qquad (4)$$

Where λ = the tuning parameter,

$\frac{1}{(\lambda s+1)^r}$ = the desired set point response and

r = the degree of P_M (s).

It is shown that the IMC controller gives very good tracking performance but not satisfying the disturbance rejection performance some times. So a secondary controller Qd is included to optimize the disturbance rejection performance.

The designed disturbance rejecting IMC controller is given as

$$Q_d(s) = \frac{\alpha_m s^m + \cdots + \alpha_1 s + 1}{(\lambda_d s+1)^m} \qquad (5)$$

Where λd is the disturbance rejection tuning parameter, 'm' is the number of poles Ṕ(s).

The feedback controller K is equals to

$$K = \frac{QQ_d}{1-PQQ_d} \qquad (6)$$

Here K is considered as the PID controller.

Direct implementation of IMC controller needs higher order transfer function knowledge if the model Ṗ is of higher order, as discussed in LFC of power system. So the IMC structure is transformed to a PID control structure.

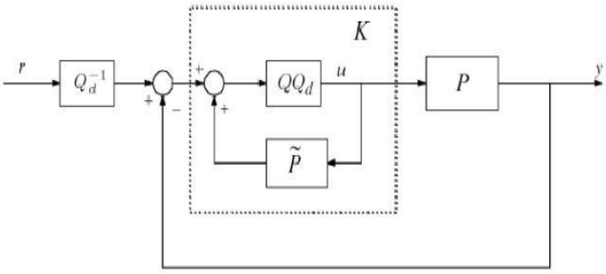

Figure 4: IMC equivalent conventional feedback configuration

The standard technique of tuning the PID parameters from IMC controllers is to expand the controller block K shown in Figure 4 in to Maclaurin series. The first three terms coefficients of the Maclaurin series are the parameters of the PID controller.

B. Load Frequency Control PID Design

The tuning of PID controller is to improve the performance of the load frequency control of power system as represented by the single area model shown in figure 5.

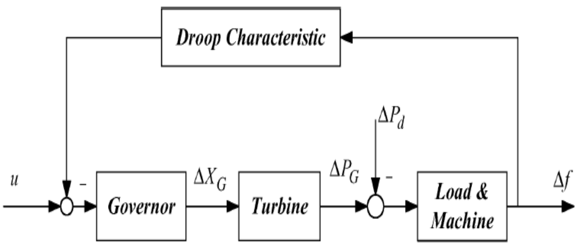

Figure 5: Linear model of a single area power system

So the control law u $= -$K(s) Δf,

Where $K(s) = K_p(1 + \frac{1}{T_s} + T_d s)$ (7)

Practically PID controller is implemented to reduce the noise effect. So K(s) can be written as $K(s) = K_p(1 + \frac{1}{T_s} + \frac{T_d s}{N_s+1})$ where N is called the filter constant.

III. Analysis And Results

The performance of IMC-PID controller are shown in figures 6 to 8. The responses shown are in form of dynamic responses of each area frequencies and the power of tie line, for the two area power system model.

Results of IMC-PID Controller for LFC of Two Area Power System

Figures 6, 7, and 8 are showing the dynamic responses of deviation in frequency for both the areas (Δf_1, Δf_2) and the power deviation in tie line (tie($\Delta P_{tie\,(1,2)}$) for a power system having two control areas with thermal non-reheat turbines. The figures show the performances of a PID controller for LFC of power system, tuned via IMC. Figures shows that the responses are stable with very less overshoot and less settling time. So PID - IMC controller is a powerful controller which gives better stability for LFC of a two area power system.

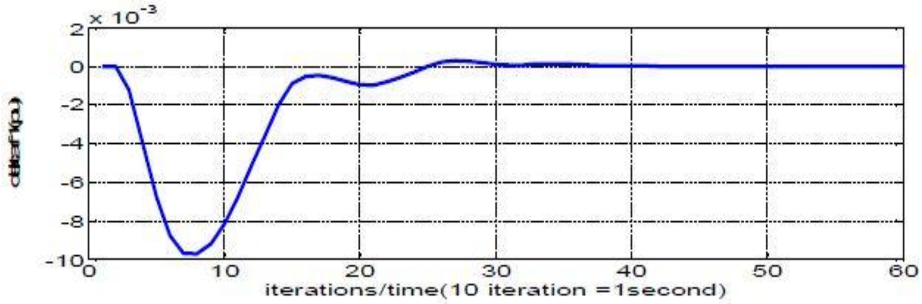

Figure 6: change in frequency V/S time in area-1 for 0.01 step load change in area-1

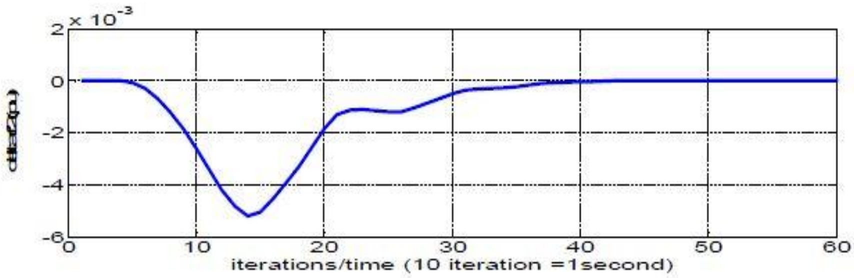

Figure 7: change in frequency V/S time in area-2 for 0.01 step load change in area-1

The figures show that the IMC-PID controller gives better response than the conventional integral controller for LFC of power system.

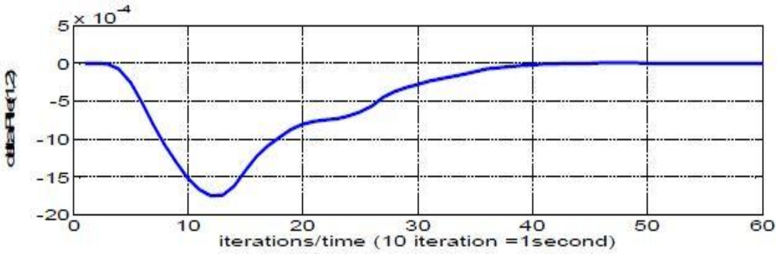

Figure 8: change in tie line power V/S time for 0.01 step load change in area-1

IV. Conclusions

Model of a two area interconnected power system has been developed with different area characteristics for optimal and conventional control strategies. The control equations have successfully been derived in continuous time for a two area power system. The model developed has been examined for the stability before and after the application of state feedback control.

An IMC-PID controller is designed for LFC of the proposed power system via Internal Model Control (IMC) and its results are compared with conventional integral Load Frequency Controller for a two area power system. So PID controller is designed on the basis of IMC controller and applied for LFC of a two area power system and well stabilized responses are obtained.

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