PID Controller Tuning using Simulink for Multi Area Power Systems

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Abstract

Practically all power systems are of multi-area in nature. Hence study of multi-area power systems (MAPS) is important. Basic problems of MAPS are Automatic Generation Control (AGC) which controls the system frequency and Automatic Voltage Regulator (AVR) that keeps system voltage constant at rated value.

PID controller is an established industrial controller. There are many methods available for tuning of PID controllers. All these methods are used as initial guess for PID controller parameter settings. Later these settings are improved by fine tuning. Now a days simulation softwares are widely popular. MATLAB Simulink is one of them. Hence we take the advantage of simulation tools and propose a method for tuning of PID controllers using simulation. This is a three step method. First step determines the gain parameter. Second step takes care of the transient performance. Third step deals the steady state performance. Finally it results in good overall performance. First this method is demonstrated in detail for Automatic Voltage Regulator (AVR) of an isolated power system. Then it is applied to a four area power system. These applications vindicate the proposed method of tuning of PID controller.

Keywords: Automatic Generation Control (AGC), Automatic Voltage Regulator (AVR), Multi Area Power Systems (MAPS), Proportional-Integral-Derivative (PID) Controller

1 **Introduction:**

The main objective of power system operation and control is to maintain continuous supply of power with an acceptable quality to all the consumers in the system. Large scale power systems are normally composed of control areas or regions representing coherent group of generators. In power system, both active and reactive power demands are never steady they continuously change with the rising or falling trend. As the power in AC form has real and reactive components, the real power balance as well as the reactive power balance is to be achieved. Changes in real power mainly affect the system frequency while changes in reactive power mostly affect the bus voltages. Quality of power supply must meet certain minimum standards with regard to constancy of voltage and frequency. There are two basic control mechanisms namely reactive power balance (for acceptable voltage profile) and real power balance (for acceptable frequency values). The former is called the Automatic Voltage Regulator (AVR) and the latter is called Automatic Generation Control (AGC). The voltage and frequency controller has gained importance with the growth of interconnected system and has made the operation of power system more reliable.

The conventional control strategy for the AGC problem is to take the integral of the area control error as the control signal. An integral controller provides zero steady state deviation but it exhibits poor dynamic performance [1–2]. To improve the transient response, various control strategies such as linear feedback, optimal control and variable structure control have been proposed [3-5]. However, these methods need some information for the system states, which are very difficult to know completely. The AGC system investigated consists of four generating areas with reheat thermal systems [6]. Four area reheat thermal system with both AGC and AVR controls are studied in [7].

Fuzzy control methods are applied to AGC problem [8-9]. However these methods also need to be fine tuned. PID controller is a powerful tool to improve both transient and steady state performances. Proper tuning of PID controllers eliminates the need for complex controllers. There are many methods available for tuning of PID controllers [10-11]. All these methods are used as initial guess for PID controller parameter setting. Later these settings are improved by fine tuning. Now a days simulation softwares are widely popular. MATLAB **Simulink** is one of them. Hence we take the advantage of simulation tools and propose a method for tuning of PID controllers using simulation. This is a three-step method. First step determines the gain parameter. Second step takes care of the transient performance. Third step deals the steady state performance. First this method is demonstrated in detail for Automatic Voltage Regulator (AVR) of an isolated power system. Then it is applied to a four area power system with AGC and AVR.

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2. Methodology:

The structure of a PID controller is

$$G_C(s) = K_P + \frac{K_I}{s} + sK_D \qquad (1)$$

where K_P, K_I and K_D are proportional, integral and derivative gain constants.PID controller tuning can be achieved in three steps. In Step 1 we select K_P that results in a highly oscillatory stable response with K_D = K_I = 0. In Step 2 we fix the parameter K_D, for K_P selected in Step1, taking care of transient performance. In Step 3 we fix the parameter K_I, for K_P and K_D selected in Steps 1 and 2, taking care of steady state performance.

Step1: First we set the gain parameter K_P. Here K_D and K_I are zero. By trial and error select K_P that results in a stable oscillatory performance. Higher K_P results in decrease of rise time and steady state error but highly oscillatory response. Higher K_P may be employed for a single input system.

In a multi input system if K_P is high it is observed that it is difficult to damp out these oscillations. Hence select a K_P resulting in near to critical damping in case of multiple inputs.

Step 2: Now using derivative control reduce the above oscillations by providing proper damping which results in reasonable overshoot and settling time. This can be achieved by varying K_D with K_P found in Step 1 and analyzing the resulting response from the corresponding simulation. So we have fixed K_P and K_D. Still K_I = 0.

Step 3: So far we have taken care of transient performance. What remains is steady state performance. Here we concentrate on steady state error. If steady state error is not zero, then for the values of K_P and K_D fixed in Step 2, vary K_I and select the K_I that results in zero steady state error in minimum time.

This completes the tuning of PID controller. Please note that sometimes Step 2 or 3 may not be required. That is PD or PI controller is good enough.

3.1 Case Study 1: AVR of Isolated Power System

The proposed methodology mentioned in Section 2 is implemented on the AVR of the following isolated power system.

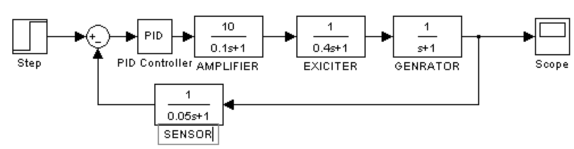

Fig1: AVR with PID controller

According to step1 select the gain parameter K_P = 6, here K_I and K_D are zero. This makes system unstable. By trial and error decreasing the value of K_P to1.1 results in stable oscillatory response. Further decrease in K_P leads to high rise time and steady state error which is not desirable. From step 2, select the gain parameter K_D such that the above oscillations are reduced, K_D = 0.2 results in damped oscillations with the selected value of K_P in step1and K_I = 0. As steady state error still exists, according to step 3 select the value of gain parameter K_I that results in zero steady state error in minimum time. K_I = 0.5 results in better steady state performance. This completes the tuning of PID controller for the AVR system. Resulting voltage response of AVR is shown in Fig 2. From the figure we note that both transient and steady state performances are good.

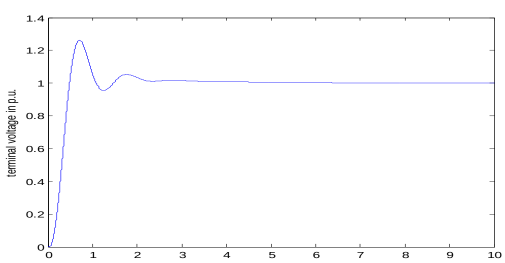

Fig2: Voltage response of AVR of isolated power system

3.2 Case Study 2: AGC and AVR Control in Multi Area Power System

In order to keep the power system in normal operating state, a number of controllers are used in practice. Because of the inherent nonlinearities in system components and synchronous machines, most of the Automatic Generation Controllers are primarily composed of an integral controller. The integrator gain is set to a level that compromise between fast transient recovery and low overshoot in the dynamic response of the overall system. This type of controller is slow and does not allow the controller designer to take into account possible non-linearity in the generator unit. . So the PID controller will be used for the stabilization of the frequency in the AGC problems. So tuning of PID controller is very important to get optimal performance.

PID controller consists of Proportional, Integral and Derivative actions. It is usually tuned by Ziegler-Nichols method. Ziegler-Nichols method is by far the most common control algorithm [12]. In this paper we propose a simple method for tuning of PID controller through MATLAB Simulink. The proposed methodology is implemented for AGC and AVR of four area power system. Fig 3 shows the simplified representation of four area power system. Fig 4 shows the Area1 (with AGC and AVR) of four area power system. Modeling of different components for AGC and AVR are taken from reference paper [7]. System parameter values are shown in Tables 1 and 2.

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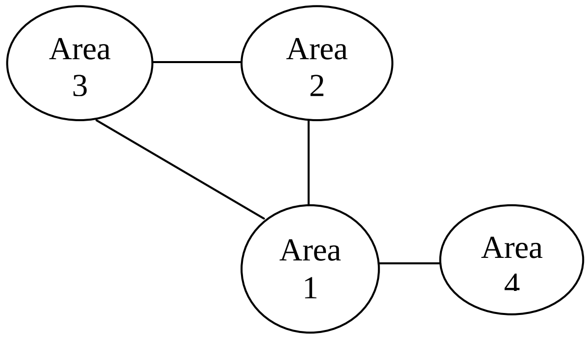

Fig 3: Simplified representation of four area power system

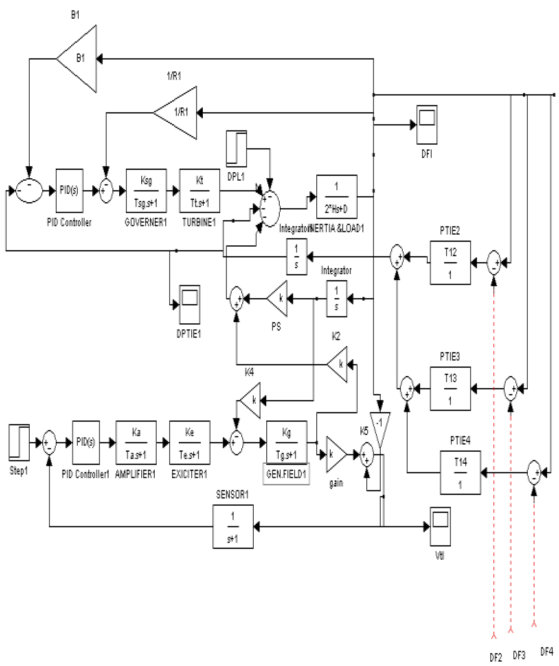

Fig4: Area1 (with AGC and AVR) of four area power system

4. RESULTS AND DISCUSSIONS:

PID controllers of the form (1) are used in AGC and AVR modeling. These PID controllers are tuned as mentioned in Section 2 and shown in Tables 3 and 4. Figs 5-12 show the resulting responses.

Fig 5, 6, 7, 8 shows the frequency responses of this four area power system with PID controller tuned by this method (Table 4) and Integral control only [7]. Fig 9, 10 shows the variation of tie-line exchange power and mechanical output power with PID controller and those of [7]. Fig 11, 12 shows the voltage response of this power system for the tuning given in Table 3 and those of [7].

From all these figures we note that the results are better with PID controller tuned by this method compared to Integral control with less overshoot/undershoot and settling time.

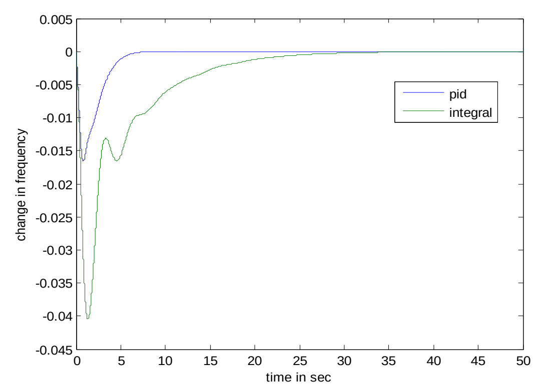

Fig5: Frequency response of area-1

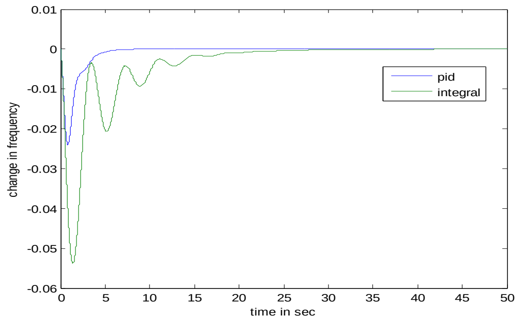

Fig6: Frequency response of area-2

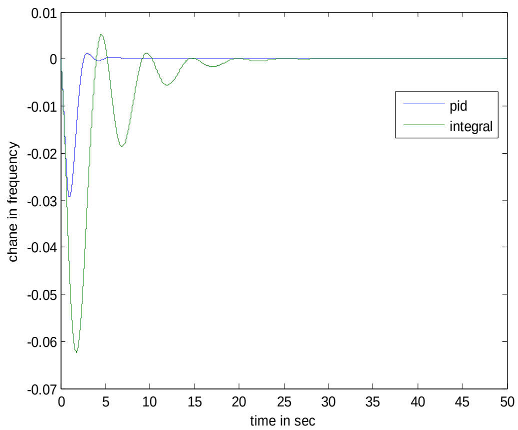

Fig7: Frequency response of area-3

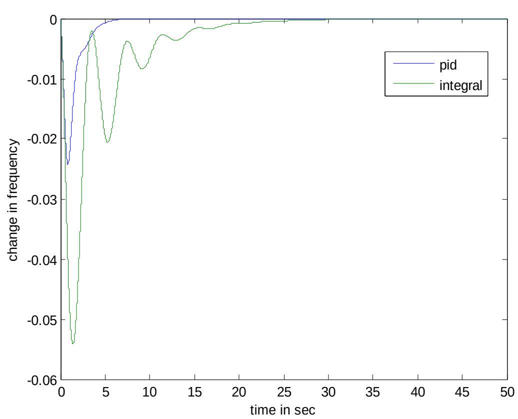

Fig8: Frequency response of area-4

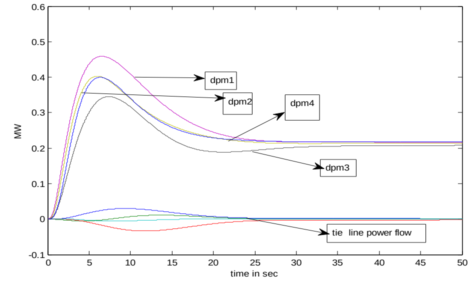

Fig9: Tie-line power of four areas with Integral controller

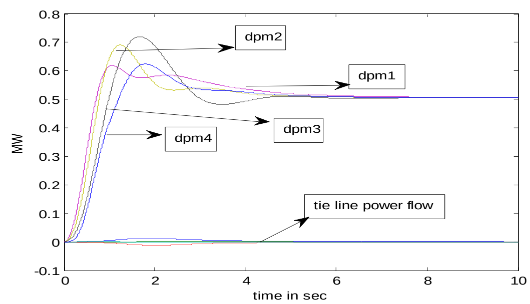

Fig10: Tie-line power of four areas with PID controller

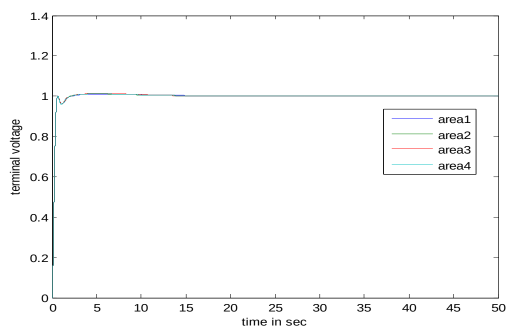

Fig11: Voltage response of four areas With integral controller

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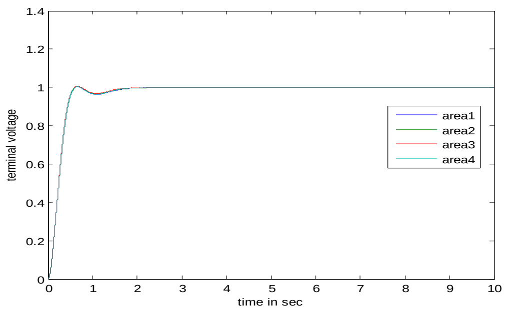

Fig12: Voltage response of four areas with PID controller

Table 1: Parameters used in simulation of AGC

Area-1 H_1=5, TT1=0.5sec, TG1=0.2sec, R1=0.051,D1=0.62
Area-2 H2=4,TT2=0.6sec, TG2=0.3sec, R2=0.065,D2=0.91
Area-3 H3=4.5,TT3=0.7sec, TG3=0.4sec, R3=0.089,D3=0.95
Area-4 H4=4, TT4=0.6sec, TG4=0.3sec, R4=0.066,D4=0.92
T12=T13=T14=T21=T23=T31=T32=T41=0.545
T24=T34=T42=T43=0
ΔP_{Li} = 0.1802 pu
TT: Turbine time constant, TG: Governor time constant, R: Regulation parameter, K_p: Power system gain, T_{ij}: Synchronizing coefficient, B: Frequency bias parameter, ΔP_{li}: load disturbance, H: Inertia constant, Base power 1000MVA,Frequency 50hz

Table 2: Simulation parameters for AVR

Component	Gain	Time constant
AMPLIFIER	9	0.1
EXITER	1	0.4
GENERATOR	1	1.0
SENSOR	1	0.05

Table 3: PID controller parameters for AVR

PID parameters	Area-1	Area-2	Area-3	Area-4
K_P	1	1	1	1
K_I	0.65	0.65	0.65	0.65
K_D	0.35	0.35	0.35	0.35

Table4: PID controller parameters for AGC

PID parameters	Area-1	Area-2	Area-3	Area-4
K_P	0.8	1	1.2	1
K_I	0.7	0.8	1	0.8
K_D	1	1	1.2	1

6. CONCLUSIONS

This paper presents a new simple tuning method for PID controller through MATLB simulink and is applied to four area power system consisting of both AGC and AVR. Case study 1 presents the proposed methodology. The case study 2 presented justifies the proposed method with better results for a MAPS. Next this method will be applied to a MAPS consisting of nonlinearities.

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