STABILITY ANALYSIS USING PID CONTROLLER FOR AUTOMATIC GENERATION CONTROL (AGC) OF MULTI AREA POWER SYSTEMS

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CERTIFICATE OF RESEARCH

This is to certify that the work presented in this thesis paper is the outcome of research carried out by the candidate under the supervision of Dr. Ashik Ahmed, Professor, Electrical and Electronic Engineering (EEE). It is also declared that neither this thesis paper nor any part there has been submitted anywhere else for the reward of any degree or any judgment.

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List of Acronyms

AGC	Automatic Generation control
GRC	Generation Rate Constraint
PIDD	Proportional-Integral-Double Derivative
IDD	Integral-Double-Derivative
PID	Proportional Integral Derivative
ACE	Area Control Error
TLB	Teaching Learning Based Optimization algorithm

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ABSTRACT

Our proposition point is identified with Stability investigation of regulator for Automatic Generation Control (AGC) of multi territory power frameworks with different energy assets. This postulation book contains an inside and out investigation of the plan and examination of Proportional-Integral Derivative (PID) regulator for Automatic Generation Control (AGC) of multi-territory power frameworks with different fuel sources. From the start, a two-zone energy framework with suitable Generation Rate Constraint (GRC) is thought of. The plan issue is detailed as an advancement issue and to advance the boundaries of the PID regulator. The prevalence of the proposed PID regulator has been shown for a similar interconnected force framework. Additionally, the proposed approach has been stretched out to two-zone power framework with assorted wellsprings of age like warm, hydro, wind and diesel units. The framework model incorporates evaporator elements, GRC and Governor Dead Band (GDB) .It is seen from reproduction results that the presentation of the proposed approach gives better powerful reactions by contrasting the outcomes and as of late distributed in the writing. Further, the examination is reached out to a three inconsistent territory energy framework with various regulators in every zone and the outcomes are contrasted and distributed FA improved PID regulator for a similar framework under investigation.

Chapter 1

Introduction

With the growing expansion of scientific and technological advancement, control systems have been integrated into all parts of our life .Control systems have made it possible for us to achieve our desired outcome by managing and regulating the behavior of control issue. In an electric power structure, Programmed Generation Control is a structure for changing the power yield of various generators at different power plants, in light of changes in the stack. Since a power structure requires that age and trouble eagerly balance step by step, incessant acclimations to the yield of generators are important. The equilibrium can be decided by estimating the framework recurrence. If it is growing, more power is being delivered than used, which makes each one of the machines in the system revive. In case the structure repeat is reducing, more weight is on the system than the quick age can give, which makes all generators postponed down. Programmed Generation Control (AGC) assumes a significant part in the huge scope multi-region interconnected force frameworks to keep up framework recurrence and tie-line powers at their ostensible qualities.

1.1 Overview of Automatic Generation Control

It is a significant control work inside a utility's energy control focus which is Automatic Generation Control (AGC), whose reason for existing is the following of burden varieties while keeping up framework recurrence, net tie-line trades, and ideal age levels near planned (or indicated) values. At the point when a few utilities are interconnected, each will play out its own AGC autonomously of the others. This decentralized control framework has functioned admirably since its presentation in the fifties, regardless of the way that around then, the lone control hypothesis apparatuses accessible were those of traditional recurrence space, single-input single-yield, frameworks. In this way AGC is a genuine archetype of the much featured late methodologies of various leveled current control hypothesis.

1.2 Thesis Motivation

There are quite a few factors that have influenced us to select Automatic Generation Control. In modern civilization we use control system in our daily life. We choose this topic because we want to improve power generation system by improving control system we can minimize generation related problem. There are certain reasons behind this choice also. All these will be discussed in this section where the primary focus is on our motivation towards selecting our research path for undergraduate level thesis.

First of all, we must know what we exactly mean by AGC. Essentially it is perhaps the main composed control frameworks present in current interconnected power frameworks. Which is important for our power generation suppose when the load of the power station increase at rush hour the generation frequency dropped significantly at that time AGC is use to minimize the change so that the system become stable.

Now comes the part we use AGC at thermal, hydroelectric generation plant. It’s fully computer based control system we use PID controller.

Another notable element motivating us towards AGC is the growing popularity of control system. Plenty of research work is being conducted in the fields of control system. Since there is plenty of scope for research work in AGC and control systems, we have selected our thesis project to be something which applies Automatic generation control using different types of algorithms. We acquire knowledge about the generation control of different generating stations.

1.4 Literature Review

This section presents a brief review of some papers which we read to acquire an idea about Automatic Generation Control.

O.I. Elgerd , Electric Energy Systems Theory [1] This book discusses the automatic closed-loop control of generators, which is the key to the successful operation of modern power plants and power systems. P. Bhatt, S.P. Ghoshal, R. Ro [7] The increasing in size and complexity in the interconnected power system makes it difficult to design a controller and analyze the performance for the entire system. Some of the above mentioned control methods could not achieve satisfactory performance since the effects of physical constraints such as GRC and load reference set-point limitation and dead band not explicitly considered in the controller design and only imposed on the systems during simulation. [10] L.C. Saikia, J. Nanda, S. Mishra, Performance comparison of several classical controllers in AGC for multi-area interconnected thermal system, This paper presents automatic generation control (AGC) of interconnected two equal area, three and five unequal-areas thermal systems provided with single reheat turbine and generation rate constraints of 3% per minute in each area. A maiden attempt is made to apply integral plus double derivative (IDD) controller in AGC. Controller gains in the two-area system are optimized using classical approach whereas in the three and five area systems controller gains and governor speed regulation parameters (R_i) are simultaneously optimized by using a more recent and powerful evolutionary computational technique called bacterial foraging (BF) technique.

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1.3 Thesis Objective

The three primary targets of Automatic Generation Control (AGC) include:

Supporting recurrence as near ostensible as conceivable to the predetermined reach. Upkeep of proper degree of traded power. Upkeep of monetary unit's age. The principle course of execution of the AGC includes use of a focal area. The reason is to telemeter the data from that focal area. It is additionally basic to understand what measure's would establish a decent AGC framework:

The Area control Error (ACE) signal should be held within proper limits from getting excessively huge. The heap variety includes an immediate impact on the ACE and in this way the quality deviation esteems ought to be negligible. There ought to be no floating of the ACE. This is significant since, in such a case that the floating happens then we will have the trouble of coincidental exchange mistakes. By a negligible float, the significance being suggested is that the ACE ought to be little. The control activity estimations of AGC ought to be little and kept that way. For example, you'll have irregular burden changes which shouldn't cause control activity. The goal is moreover to be prepared to screen brilliantly. Along these lines, the framework can direct those occasions/measures which are important instead of the irregular ones which have no impact.

Chapter 2

Mathematical Model and Control Structure

2.1 Model of a Two-area Power System

In two territory power framework, each single region has number of generators which are firmly coupled together in order to shape a such an intelligent region is known as a control region wherein the recurrence is thought to be the equivalent all through in static just as unique circumstance.

A particularly intelligent zone is known as a control region where the recurrence is thought to be the equivalent all through in static just as powerful circumstance. At first the adjustments in load are overseen by the speed administering framework.

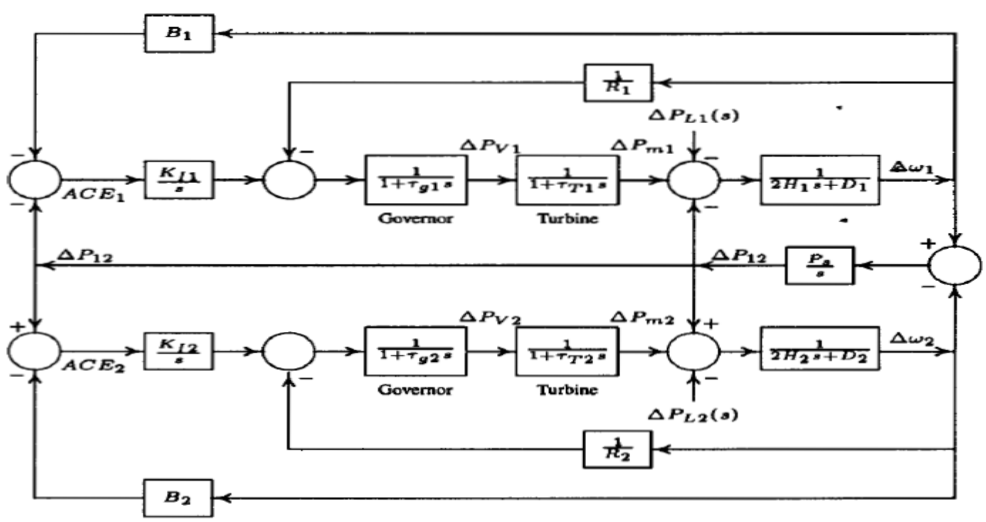

Figure 2.1: AGC block diagram for a two area system.

In Fig. 2.1, B1 and B2 are the recurrence predisposition boundaries; ACE1 and ACE2 are zone control blunders; u1 and u2 are the control yields from the regulator; R1 and R2 are the lead representative speed guideline boundaries in p.u. Hz; TG1 and TG2 are the speed lead representative time constants in short order; ΔPG1 and ΔPG2 are the lead representative yield order (p.u.); TT1 and TT 2 are the turbine time consistent like a flash; ΔPT1 and ΔPT 2 are the adjustment in turbine yield powers; ΔPD1 and ΔPD2 are the heap request changes; KP1 and KP2 are the force framework gains; TP1 and TP2 are the force framework time steady right away; T12 is the matching factor in p.u.; ΔPTie is the gradual change in tie line power (p.u.); ΔF1 and ΔF2 are the framework recurrence deviations in Hz.

2.2 Controller Design and Target Work

During some decades ago, many progressed control constructions and calculations have been proposed and applied to liberated interconnected power frameworks. Notwithstanding, not many of these plans are totally satisfactory. Thusly, three control plan procedures have been investigated in writing, to be specific brought together, decentralized and circulated control frameworks. Traditional PID regulators are utilized in a large portion of the modern cycles because of their basic and powerful plan, minimal effort, and viability for direct frameworks. So we use, PID regulators in our recreation to tackle the AGC issue. Taking into account the way that examination has been done on a two-equivalent zone non-warm turbine nuclear energy framework, comparative sorts of PID regulators are considered in the two territories. The plan of PID regulator requires assurance of the three primary boundaries: Proportional gain (KP), Integral gain (KI) and Derivative time consistent gain (KD).

Chapter 3

Theoretical Backgrounds

3.1 Single Area power System Area:

To build up any control technique it is important to make a numerical demonstrating of that framework. It is helpfully accepted that each control region can be addressed by identical turbine, speed administering framework, generator and burden.

The square graph for single region power framework is appeared in Figure

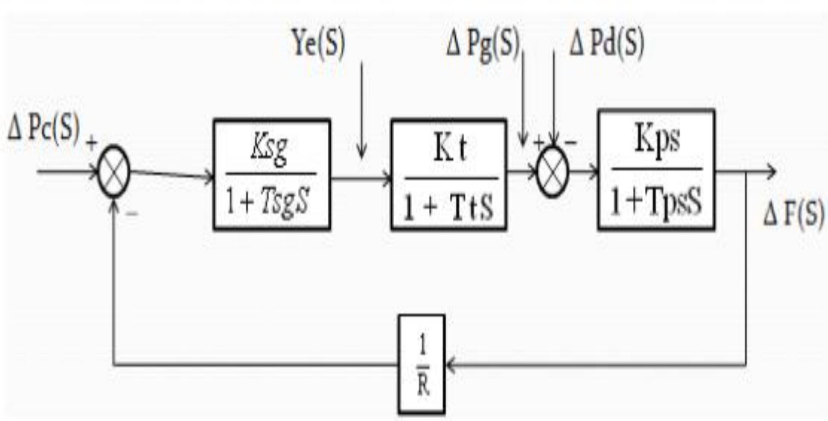

Figure 3.1: AGC (automatic generation control) block diagram for a single area system.

3.2 Two Area Power System

In two territory power framework, each single region has number of generators which are firmly coupled together in order to shape a reasonable gathering, for example every one of the generators in power framework ought to react as one to change in load. A particularly reasonable region is known as a control zone in which the recurrence is thought to be the equivalent all through in static just as powerful circumstance. At first the adjustments in load are overseen by the speed administering framework.

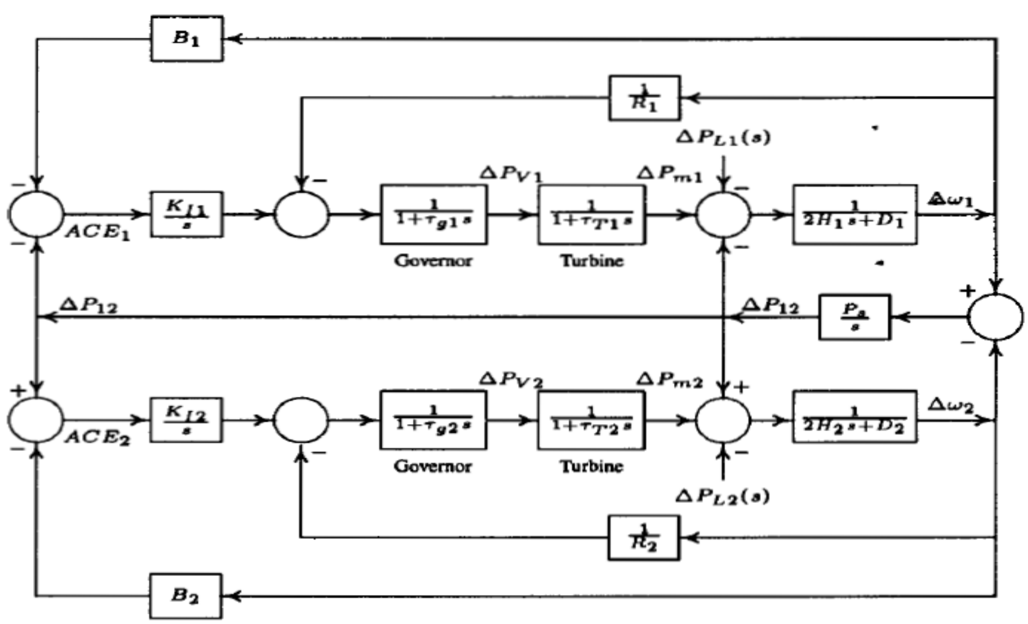

Figure 3.2: AGC(automatic generation control) block diagram for a two area system.(new model after addition of control areas)

3.3 Tie Line

The transmission lines which associate a territory to its adjoining region are called tie-lines. The force dividing among two regions is done through these tie-lines.

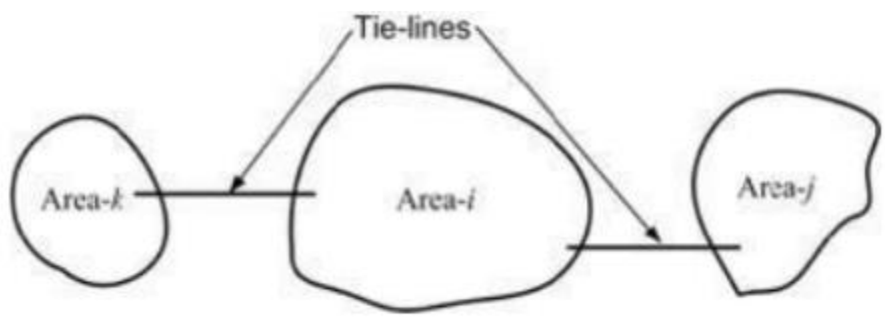

Figure 3.3: Inter connected power system

Load frequency control: as its name implies that it manages the power stream between various zones while keeping the recurrence consistent**.**

Chapter 4

Methodology

4.1 Introduction:

We are going to see how to design **automatic generation control** of **two area power system** using **matlab/simulink.** A power system with two area and those are connected by a tie line has some parameters given below. This parameters are given on a common base of 1000 MVA. Before that a figure is given on two area system with only primary LFC loop.

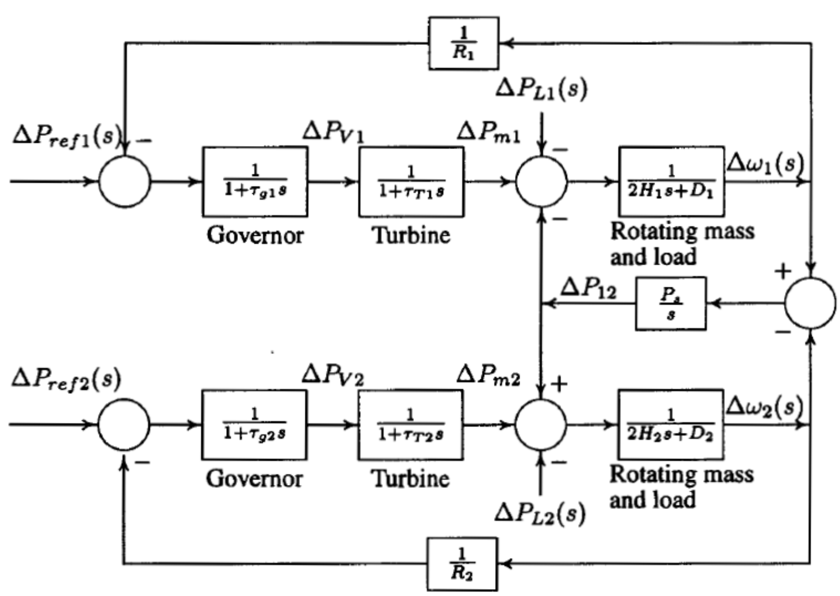

Figure 4.1: Two area system with only primary LFC loop.

Area 1 has speed regulation of 0.05 and area 2 has 0.625.

Area 1 has frequency sensitive load coefficient 0.6 and area 2 has 0.9.

Area 1 has inertia constant 5 and area 2 has 4.

Area 1 and area 2 has the same base power as 1000 MVA.

Area 1 has governor time constant as 0.2 second and area 2 has 0.3 second.

Area 1 has turbine time constant 0.5 second and area 2 has 0.3 second.

Nominal frequency for the two units is 60 Hz. Suddenly, in area 1, a load change of 187.5 MW has occurred.

Now we will see the effects of changing load.

4.2 Effects of Changing Load:

Due to this system frequency will vary as well as the power plants have to enhance their generation in order to meet the increased load demand.

In this situation, the steady state frequency and the change in the tie line power flow has to be calculated by us.

The speed regulation of Area 1 and 2 is given by:

$1/R_1 = 1/0.05 = 20$

$1/R_2 = 1/0.0625=16$

The inertia and load for area 1 and 2 is given by:

$1/(2H_1s+ D_1) = 1/(2*5s +0.6)=1/(10s+0.6)$

$1/(2H_2s+ D_2) = 1/(2*4s +0.9)=1/(8s+0.9)$

The per unit load change in area 1 is given by:

$\Delta P_{L1} =187.5/ 1000 =0.1875$ p.u.

The per unit steady state frequency deviation is

$\Delta\omega= - P_{L1} /[(D_1 + 1/R_1)+ (D_2 + 1/R_2)] = -0.1875/[(20+0.6)+(16+0.9)] = -0.005$ p.u.

The change in mechanical power in each phase is

$\Delta P_{m1} = - \Delta\omega/ R_1 = - * - 0.005/ 0.05 = 0.1$ p.u. $= 0.1 * 1000=100$ MW

$\Delta P_{m2} = - \Delta\omega/ R_2 = - * - 0.005/ 0.0625 = 0.08$ p.u. $= 0.08 * 1000=80$ MW

Thus, steady state frequency deviation in Hz is

$\Delta f_{actual} = \Delta f_{p.u.} * f_{base}$ = -0.005*60 = -0.3 Hz

The steady state frequency in Hz is given by

$f_{actual} = f_{original} + \Delta f_{actual}$ = 60-0.3=59.7 Hz

The tie line power flow is $\Delta P_{12} = \Delta\omega + (D_2 + 1/R_2)$ = -0.005*[16+0.9] = -0.0845 p.u.

ΔP_{12} = 0.0845 p.u. *1000 = -84.5 MW

That is, 84.5 MW power flows from area 2 to area 1.

80MW comes from the increased generation in the area 2. The rest 4.5 MW comes from the reduction of area 2 load due to frequency drop.

4.3 Problems In Practical Power Stations:

In this state we will see some practical problems in power stations we have discussed so far:

1) In area 1, a load change of 187.5 MW has occurred. However, from these results, it has been observed that both generators have enhanced their generation to meet the increased load demand.

Practically this is not true. In the real practice, if sudden load is changed in any area, then each area has to absorb its own changes or in other words, it has to be supplied by the generator of that area only.

It means that, for the load change of 187.5 MW, the change in mechanical power of area 1 should be increased to 187.5 MW only. Whereas, the mechanical power of area 2 must remain zero. Furthermore, the change in tie line power should also remain zero.

2) Furthermore, it may be noted that frequency of the system has reached up to 59.7 Hz. It has not recovered to 60 Hz.

Due to which despite of 187.5 MW change in load, only 180 MW of load has been supplied by both generators. It still lacks 7.5MW. When frequency will recover to 60 Hz, both generators will able to supply the whole 187.5 MW.

It means that, we need to use some controlling techniques in order to take back the nominal frequency to 60 Hz which is nominal value for the frequency.

3) Moreover, it may be noted that, change in mechanical power of of generator 2 is 80 MW. It means that 80 MW power is supplied from area 2 to area 1

through tie line. However, the simulation results have shown that the tie line power flow is 84.5 MW. Now question may arise that how it is possible?

The answer is that 80 MW power is supplied from area 2, whereas 4.5 MW of power is dropped in area 2 due to frequency drop. It is because frequency stays in 59.7 Hz.

This reduction in frequency causes the reduction in load, due to which the additional power of 4.5 MW also flows towards area 1. Therefore, 84.5 MW of power flows from the tie line.

We will solve these problems by matlab simulink. To do this, we need to change our model.

4.4 Solutions of practical problems:

Now in this state we will find the solutions of the practical problems we found earlier:

1) Whole 187.5 MW of load is supplied by area 1:

Conventional LFC(load frequency control) is made up on the value of tie line bias control. Here, each area tries to decrease the area control error (ACE) to zero(or 0). For each area, the control error is given as below:

$ACE_i = n \ \Sigma \Delta P_{ij} + (K_i * \Delta \omega) \ j = 1$

The quantity of interaction during a load change in the surrounding areas is calculated by the bias of area K_i.

When K_i is selected same as the area frequency bias factor of that area given by the following way, an overall develped performance is achieved:

$B_i = \mathbf{D_i} + 1/R_i$

So for area 1

$B_1 = \mathbf{D_1} + 1/R_1 = 20.6$

And for area 2

$B_2 = \mathbf{D_2} + 1/R_2 = 16.9$

So the ACE for system with two area are

$$ACE_1 = \Delta P_{12} + (B_1 * \Delta \omega_1)$$

$$ACE_2 = \Delta P_{21} + (B_2 * \Delta \omega_2)$$

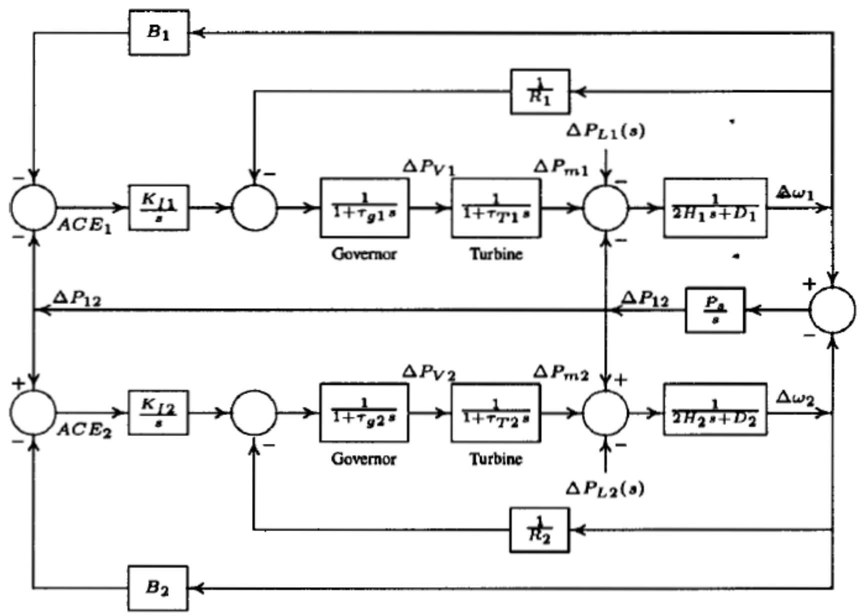

Figure 4.2: AGC block diagram for a two area system.

Now from these we are going to add our PID controller in the model.

Chapter 5

Result and Discussion

For all the simulations the simulation time is taken as 50 sec.

5.1 No Change of Load Condition

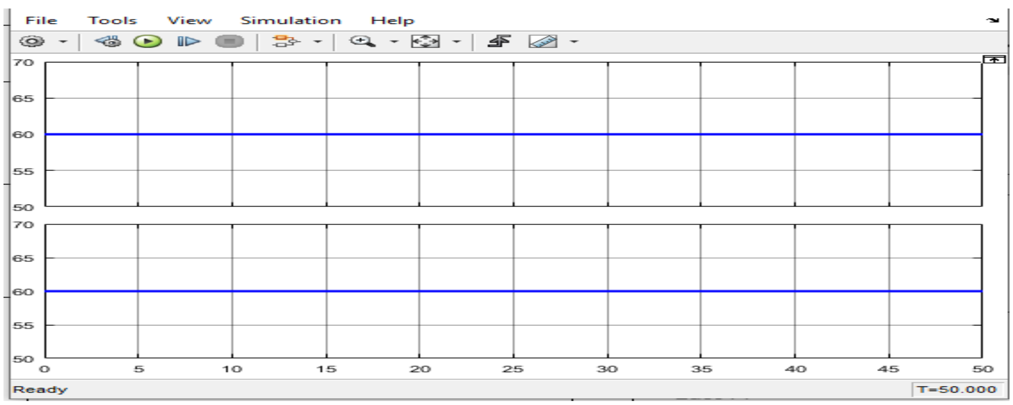

Figure 5.1: No load f1 & f2 (Hz) Vs time (s) plot

We can see as there is no change of load demand from the consumer side in any of the two areas, both the plants are running with their nominal frequency 60 Hz (from fig 5.1).

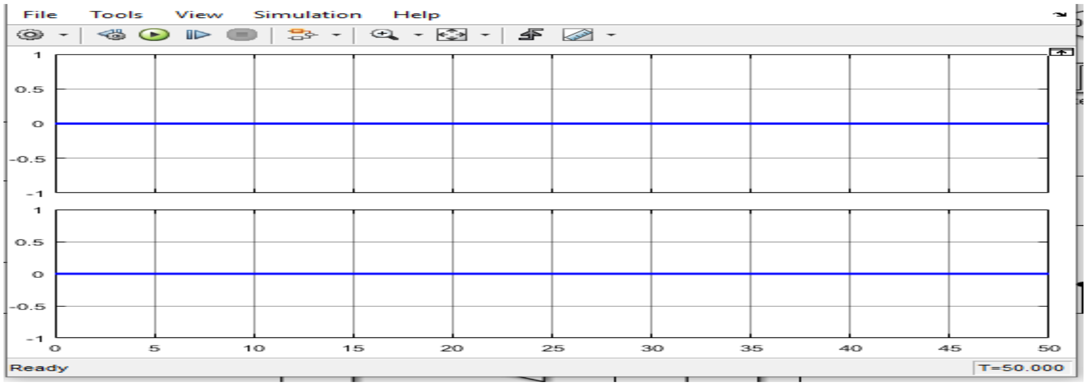

Figure 5.2: No load ΔPm1 & ΔPm2 (MW) Vs time (s) plot.

As there is no change in the load demand so there shouldn't be any change in the mechanical power of the generation (from fig 5.2)

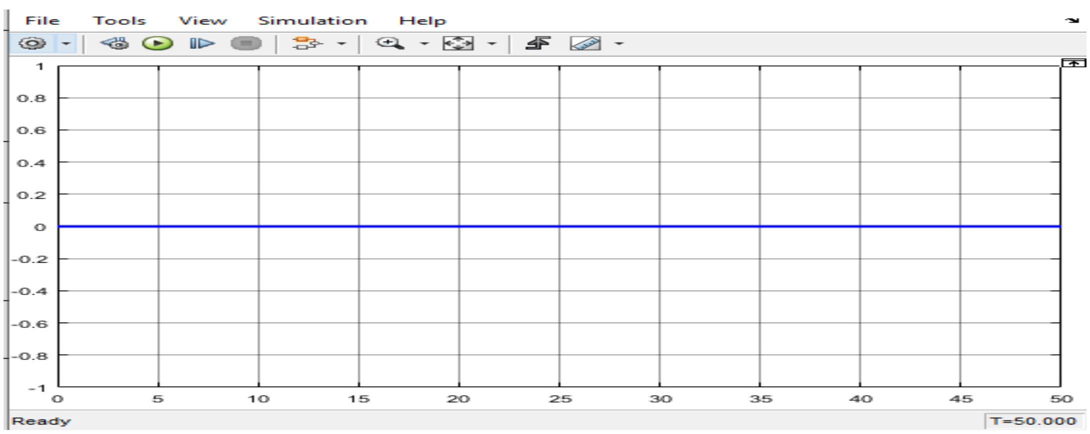

Figure 5.3: No load ΔPtie (MW) Vs time(s) plot.

When there is no additional mechanical power is supplied from any of the generating stations there shouldn't be any tie line power flow (from fig 5.3)

5.2 Change of Load Condition

Now load demand is increased by 187.5 MW in area 1

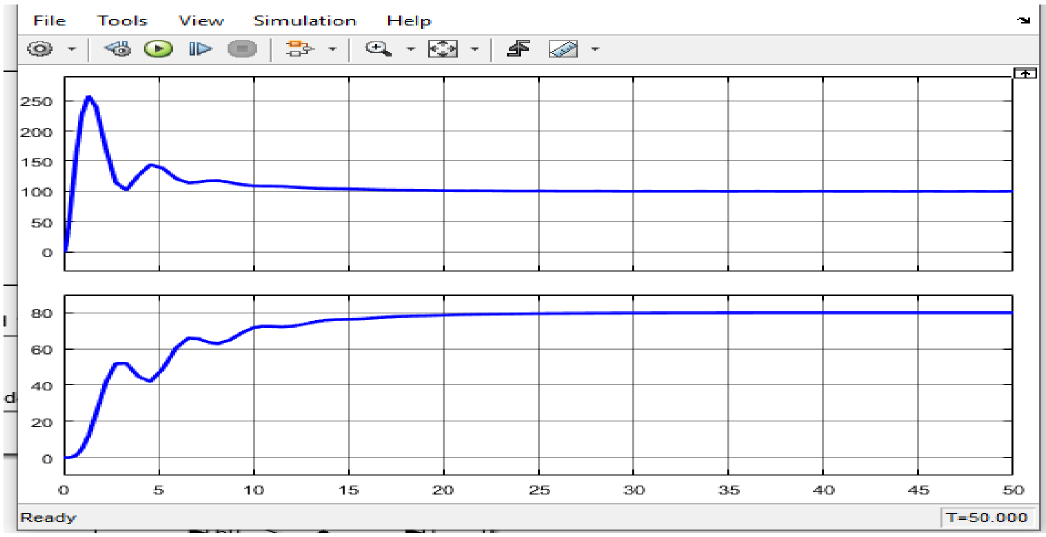

Figure 5.4: ΔPm1 & ΔPm2 Vs time (s) plot for 187.5 MW change in load demand in Area 1.

Now we can observe that when 187.5MW load demand is increased in area 1,Both of the generating stations are contributing to meet this demand. 100MW power are supplied by area 1 and 80MW power are supplied by area 2, that is actually the change in mechanical power in both the generating stations (from fig 5.4) But it is not desirable. The total 187.5 MW power should be supplied by area 1 only.

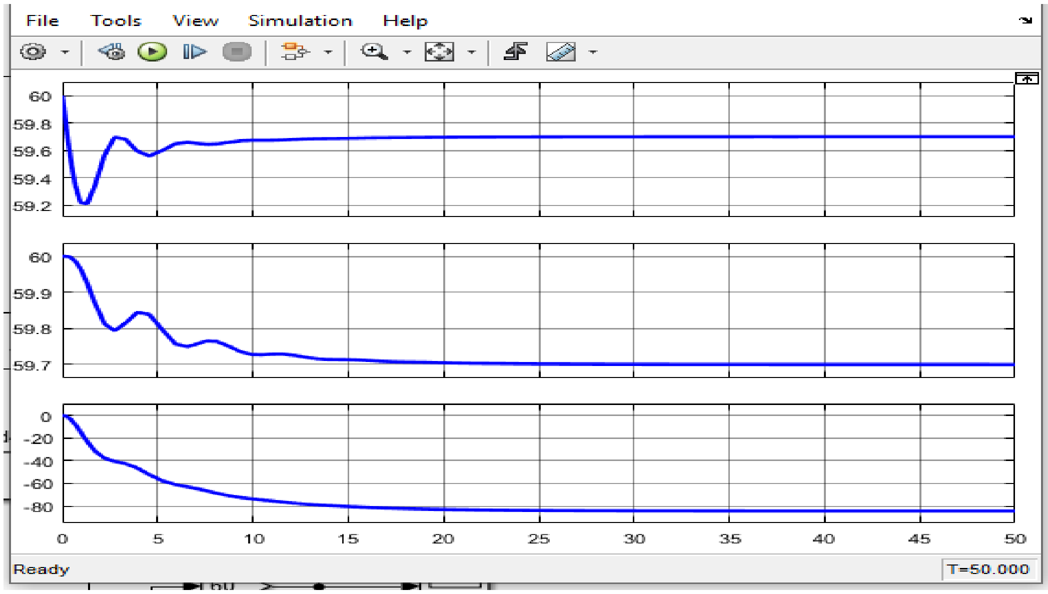

Figure 5.5: f1,f2& ΔPtie Vs time(s) plot for 187.5 MW change in load demand in Area 1.

We can see from fig 5.5 that, there is a tie line power flow of (-80)MW, that means 80MW power is supplied from area 2 to area 1. Here the plants are also not operating in their nominal frequency 60Hz, rather it has been decreased to 59.7 Hz. Which creates various types of losses in the system and also the efficiency is decreased. Now to solve this problems we have used PID controller in our model.

5.3 Using PID Controller

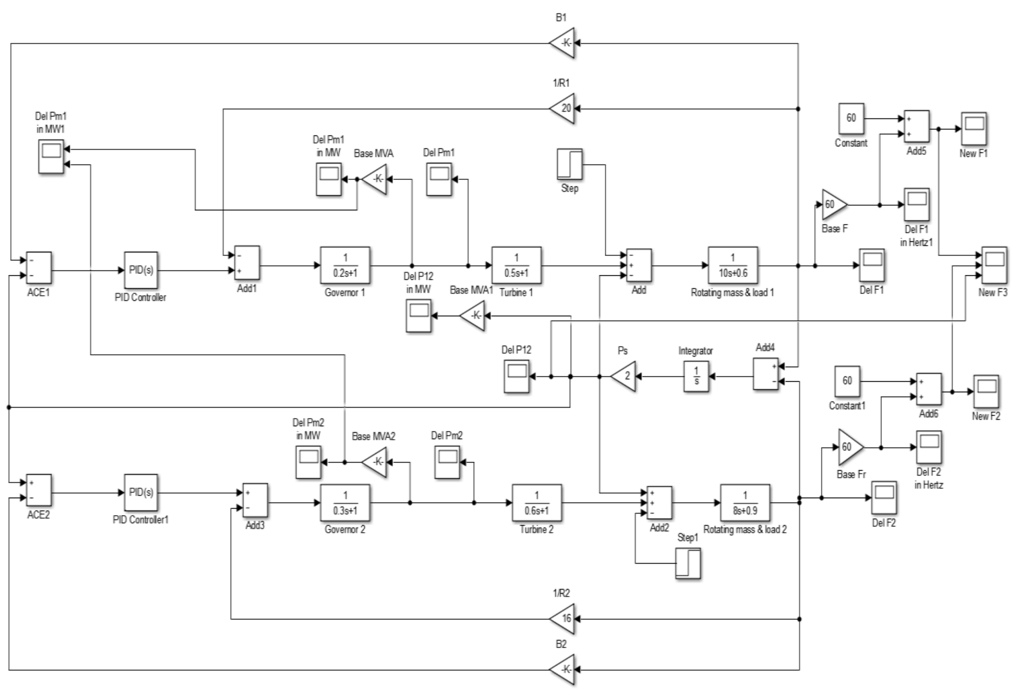

Figure 5.6: SIMULINK Model of a system with two area with PID controller.

Solving the difficulties we faced in 5.2

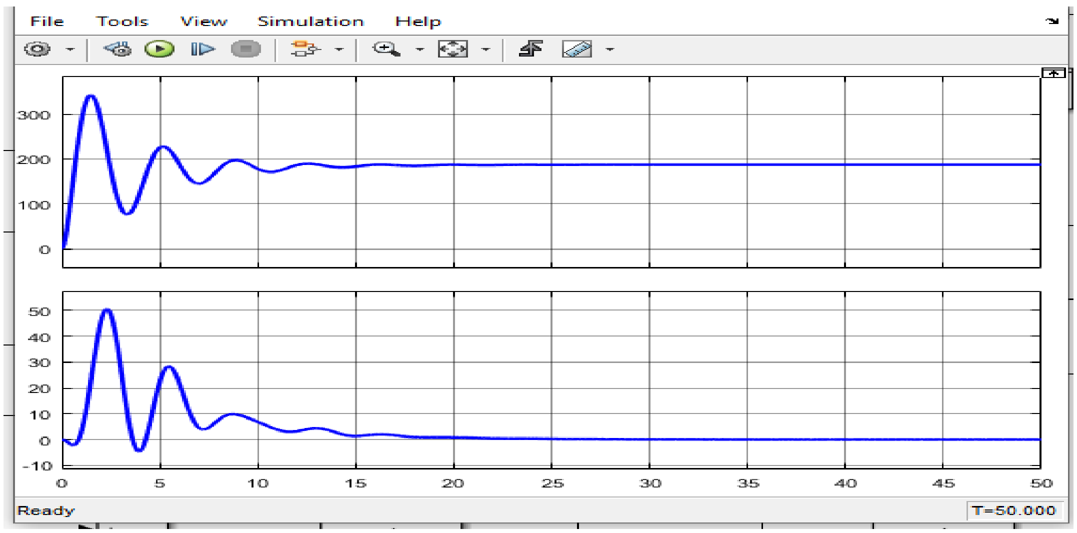

Figure 5.7: ΔPm1& Δ Pm2 Vs time (s) plot after using PID controller.

Here after using the PID controllers with the gains B1,B2 we observed that, The mechanical power change in area 2 is 0MW,that means no extra power is generated by area 2 to meet the change in load demand (from fig 5.7). Therefore the whole 180MW is supplied by area 1 only.

There might be one question that why the supplied power is 180 MW in stead of 187.5 MW, this is discussed in section 4.4.

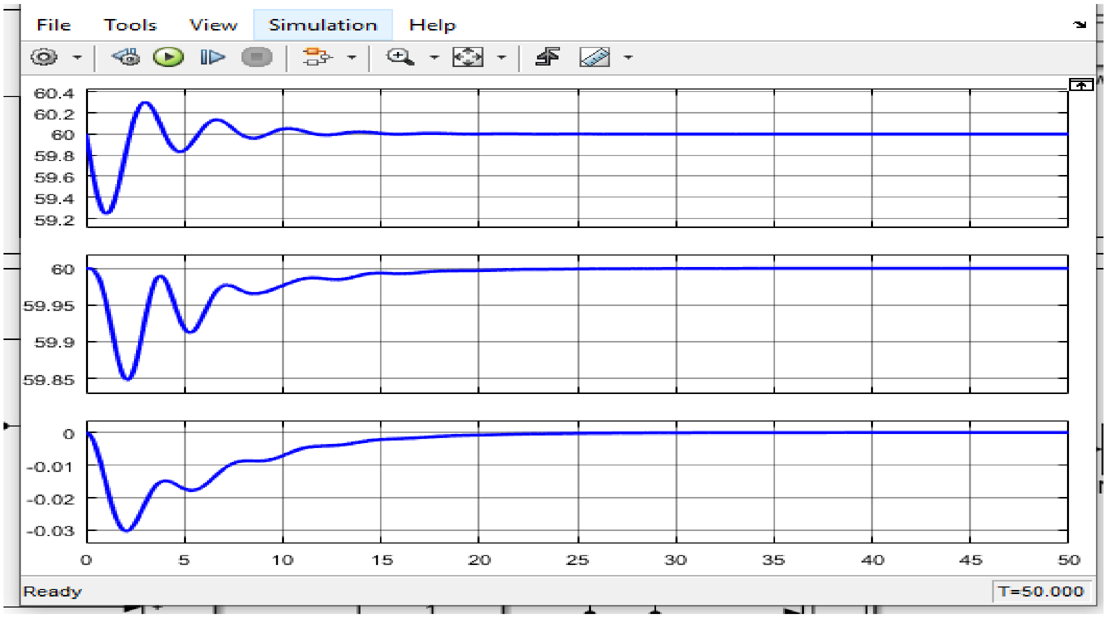

Figure 5.8: f1,f2& ΔPtie Vs time (s) plot after using PID controller.

The tie line power flow is 0 MW here, and the plants are also running with their nominal frequency 60 Hz.(from fig 5.8)

5.4 Change in Load Demand in both the Areas Simultaneously

Load demands in area 1 and area 2 is increased by 100 MW and 50 MW respectively.

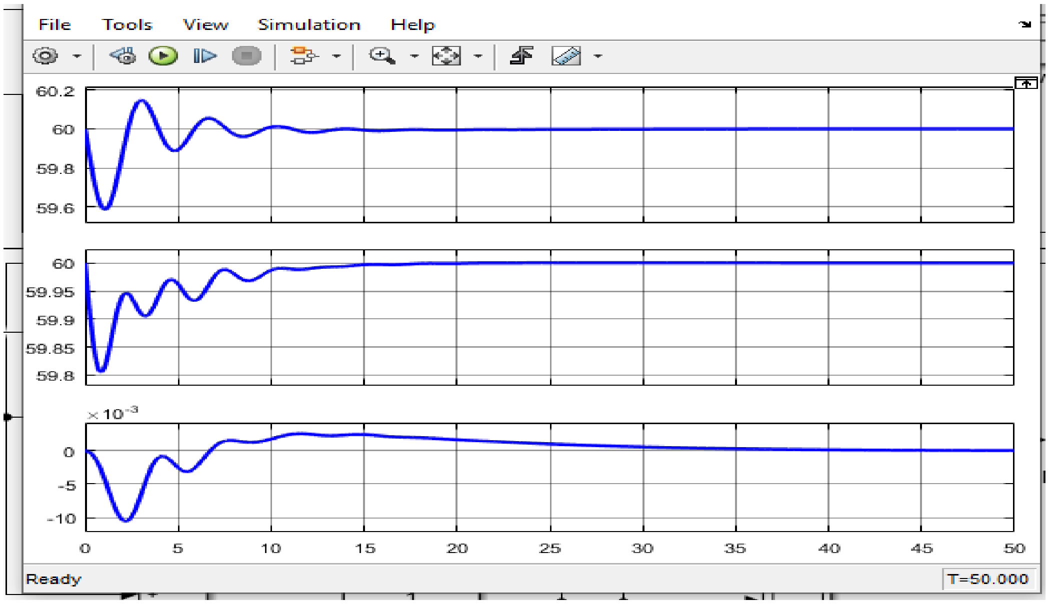

Figure 5.9: After using PID controller f1,f2& ΔPtie Vs time (s) plot plot for changing load in both the areas.

After changing the load demands simultaneously in both the areas we can see the mechanical power change in area 1 and area 2 is 100 MW and 50 MW respectively. That means 100 MW is supplied by area 1 and 50 MW is supplied by area 2 (from fig 5.9).

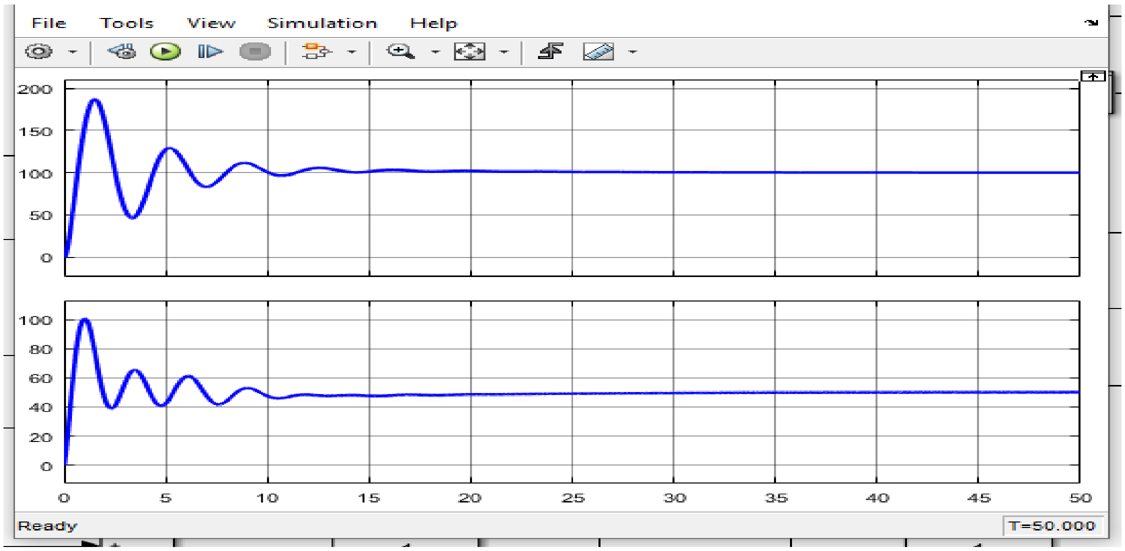

Figure 5.10: After using PID controller ΔPm1& Δ Pm2 Vs time (s) plot for changing load in both the areas.

From fig 5.10 we can observe that the Tie line power flow is 0 MW. We can also observe that in this case the plants are operating with their nominal frequency 60 Hz also.

Chapter 6

Conclusion and Future Implementations

6.1 Conclusion

The main two objectives of our research was to decrease the power flow of tie line as less as possible with maintaining the generating station's frequency of at their nominal value that means to maintain the stability of the system. After using PID controllers in both the areas our desired results were obtained and that fulfills the objectives of our research. And also we were able to reduce the tie line loss power that means the overall efficiency of the system is increased.

6.2 Future Implementations

There are several ways to improve the standard of this model. Some of them are:

- To use some advanced algorithms like TLBO,FA,BFOA,GA,ZN,BF etc to tune the PID controller parameters rather than using the SIMULINK auto tuner.
- Trial and error methods to find the best values of PID controller parameters.
- By using other controllers like IDD, PI etc.

In future by applying these techniques the system standard as well as overall efficiency can be increased.

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