

LOAD FREQUENCY CONTROL OF MULTI-AREA SYSTEM USING RENEWABLE ENERGY SOURCES

Project report submitted in partial fulfilment of the requirement for the degree of

Bachelor of Engineering degree in
Electrical and Electronics Engineering
by

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**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDECERTIFICATE

This is to certify that this Project Report is the bonafide work of **K.LALITHA LAHARI**(Reg No. 38140703), **T.PALLAVI SRI** (Reg No. 38140057)Who carried out the project entitled "**Load Frequency Control for Multi-Area system using Renewable energies**" under my supervision from September 2021 to April2022.

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Internal guide

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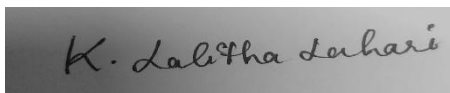
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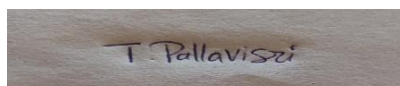
DECLARATION

We **K. LALITHA LAHARI** (Reg No. **38140703**) and **T. PALLAVI SRI** (Reg No.**38140059**) hereby declare that the Project Report entitled “**LOAD FREQUENCY CONTROL OF MULTI-AREA SYSTEM USING RENEWABLE ENERGIES**” done by us under the guidance of **Dr.V. SIVACHIDAMBARANATHAN** is submitted in partial fulfillment of the requirements for the award of a Bachelor of Engineering degree in Electrical and Electronics Engineering.

1.

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2.

A rectangular box containing a handwritten signature in black ink that reads "T. Pallavi Sri".

DATE:20-4-2022

PLACE:Chennai

SIGNATURE OF THE CANDIDATES

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ABSTRACT

Today fossil fuels prices have increased and it is a matter of concern that they will run out altogether in the future. Therefore, a shift in Renewable Energy Source utilization technology is the main concern today in power industries. Furthermore, Renewable energies are clean, inexhaustible, and eco-friendly. We are still a long way from releasing their full potential. The primary reason for this is that renewable energy sources are inherently unreliable over time. As a result, constructing large-scale power plants relying on a single renewable energy source has been deemed unworkable. According to technical and economic research, integrating a variety of renewable energy sources is critical for optimizing the use of renewable energies. This has resulted in the power to be generated using hybrid generating systems. The concept of a hybrid generating system opens up the route for power generated using different renewable energies. This hybrid generating system is most useful for supplying power in rural, urban, and remote areas. The hybrid generating system we are using is **DISH STRILING THERMAL SOLAR(DSTS) AND WIND TURBINE SYSTEM(WTS)**. The primary objective of the project is to keep up the **POWER FLOW throughout TIE-LINE OF EACH AREA** with pre-determined value, to minimize the error of the system, and to maintain constant frequency against any load variation. Here we are using the **MATLAB SIMULINK** model to simulate the areas and analyse the output of load variation.

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LIST OF ABBREVIATIONS

LFC:LOAD FREQUENCY CONTROL
PID :PROPORTIONAL INTEGRATOR DERIVATIVE
PI : PROPORTIONAL PLUS INTEGRAL
GA :GENETIC ALGORITHM
ACE: AREA CONTROL ERROR
LCOA : LOZI-MAP CHAOTIC OPTIMIZATION ALGORITHM
BFO: BACTERIA FORAGING OPTIMIZATION ALGORITHM
FLC :FUZZY LOGIC CONTROLLER OPTIMIZATION
TF : TRANSFER FUNCTION

CHAPTER 1

INTRODUCTION

1.1 Research Background

Power generation is the main cause of industrial pollution. Mostly our electricity comes from renewable and other non-renewable power plants. The energy produced from these resources leads to high chances of environmental pollution. It is not that we can fully control the harm which is being produced by generating electricity, with the use of renewable energies we can control and the harm that is caused to the environment is very less as it is feasible to generate electricity using renewable energy sources without emitting harmful gases like carbon dioxide (CO₂), which is also the major cause of change in global climate. Renewable energies provide a lower risk of fuel spills and decrease the cost of fuels, reducing transportation. Renewable energy also helps to utilize the country's natural resources.

The main purpose of a power system is to maintain constant and protected operation through keeping up a balance between power generation and heavy load needs. This kind of balance is kept up a complex network to hold the frequency of the network within the proper control in the grid network. In existing operations, there is a frequent continual change in the load pressure that creates a steadiness between the load and generation. This comparative balance always impacts the system frequency and eventually attacks the safety of the power system's functioning. The power system's frequency is mainly controlled using two control loops, namely primary and secondary. The primary control loop avoids instant variations in the frequency before using the frequency protection switches. It is provided by governor droops which are responsible for steady-state error.

The peripheral control loop also calls as automatic AGC / LFC, is used to adjust the network frequency to its momentary utility in the power system. The modern infrastructure of power generation gave some the considerable changes:

- (a) A large scale integration of sustainable energy sources,
- (b) The up to date ideas in the power network in particular microgrids and smart grids and
- (c) The power systems are digitalized.

1.2 Motivation

As we know that when there happens a load variation because of the consumer convenience then the frequency of the entire microgrid gets disturbed and starts fluctuating. This is a very large and serious problem because it can damage the equipment being supplied from this source. To improve this problem many professors, researchers, and authors have studied the problem and have done their work. They have also found many technological ways to solve it. Many have given their thesis too. This is the reason, I and my friend are motivated to contribute something to solve this problem.

1.3 Chapter organization

This report has been organized in the following given manner: -

Chapter 1 - Describes the introduction part.

Chapter 2 – A literature survey.

Chapter 3 - Describes microgrid configuration and modelling in which renewable energies have been explained.

Chapter 4 - Describes the LFC of the microgrid with some simulations.

Chapter 5 – Describes the different techniques of optimization with results and analyses the output.

Chapter 6– Conclusion and future works.

Chapter 2

LITERATURE SURVEY

The basic goal of power system control and management is to keep the power of acceptable quality. The LFC problem mostly occurs in linked grids of power systems.

The paper of C. Concrida and L.K. Kirchmayer has done a lot of work about LFC. Ollel. Elgerd has done excellent work on LFC in power systems.

For a dependable power supply despite load fluctuations, a power system frequency should be kept constant. To maintain a constant frequency, we came up with different algorithms that have been introduced. A genetic algorithm is used to identify the controller's feedback gains and switching problems. The Genetic Algorithm is mostly used to find short paths and its robust and adaptive method is used to solve and search problems it was introduced by Jang Sun Chun. John Holland has done great work on Genetic algorithms.

Chapter 3

MICROGRID CONFIGURATION AND MODELLING

3.1 Definition of microgrid

A microgrid is a very small-scale power generation system that can work independently or together with other power plants. Any type of small power plant which is capable of generating and storing power and has definable boundaries can be considered a microgrid.

Microgrids are generally assisted by wind energy and solar energy and are generally used for supplying backup power to the main power grid when heavy loads are demanded.

3.2 Wind Turbine Generator

The output is in the form of mechanical energy of a wind turbine is

$$P_w = \frac{1}{2} \rho A C V^3 \quad \text{----->eq.1}$$

Where ρ =density air = 125g/ m^3

A= area swept by blades

C= tip speed ratio λ & blade pitch angle β

V = velocity of wind (m/s)

We can write the TF of the Windturbine Generator as

$$G_W = \frac{K_W}{1 + T_W s} \quad \text{-----> q.2}$$

Where , K_W = gain

T_W = time constant

3.3 Diesel generator

This system has very high efficiency and quality of quick startup. In this, we connect a diesel engine and a synchronous generator. The electrical output that we get from this system is used to balance the power deficiency in the microgrid. Sometimes it is also used to compensate for the rise or fall of wind power for a short interval of time.

The transfer function can be written as

$$G_D = \frac{K_D}{1 + T_D s} \quad \text{-----> q.3}$$

Where, K_D = gain

T_D = time constant

3.4 Battery Energy Storage System

This storage system may be constructed by using a large number of batteries., This system is capable of acting as a generator and load too. When the

frequency increases function can be charged and when frequency decreases gets discharged.

Its transfer function can be written as $G_B = \frac{K_B}{1 + T_B s}$ -----> q.4

Where, K_B = gain

T_B = time constant

3.5 Fuel cell generator

Fuel cells convert chemical energy into electrical energy. There occurs chemical reaction. In this reaction, the hydrogen fuel is split into ions and electrons at the anode. The positively charged ions(+) go through the proton exchange area and the negatively charged electrons(-) flow through the output circuit.

Its TF can be written as

$$G_F = \frac{K_F}{1 + T_F s} \quad \text{-----> q.5}$$

Where, K_F = gain

T_F = time constant

3.6 Aqua electrolyser system

In this system, there occurs a chemical reaction known as a redox reaction. The reaction of reduction occurs in which electrons combine together with hydrogen ions to form hydrogen gas. This system takes power from renewable sources such as solar and wind energy.

Its transfer function can be written as

$$G_A = \frac{K_A}{1 + T_A s} \quad \text{-----> eq.7}$$

Where K_A = Gain

T_A = Time constant

Chapter 4

LOAD FREQUENCY CONTROL OF MICROGRID

4.1 Definition of LFC

The study of real power and frequency control together is called LFC. It is used to maintain the balance between load and power generation in each control area using speed control. The purpose of LFC is to reduce the divergence at the moment and steady-state error to zero ahead of time.

4.2 LFC of multi-area system

In such a system, every area consists of a large no. of sources that are similarly combined together to form a unified category. This kind of unified zone is called an operating zone in which the frequency is taken to be constant all over the stable as well as active situations. In this system to reduce the frequency fluctuations further PI controllers are used.

4.3 PID CONTROLLER

A PROPORTIONAL INTEGRAL DERIVATIVE controller (PID Controller) is a feedback-based control loop that is mostly used in commercial control systems and a variety of other uses require continuously adjusted control.

- Proportional (P)- It decreases the error responses.

- Hence, PID IMPROVES thenetwork STABILITY.**

Block diagram of a PID controller. The input signal splits into three parallel paths. The top path goes through a proportional gain block (K_p) and then to a summing junction. The middle path goes through an integral gain block (K_i) and an integrator block ($\frac{1}{s}$) before reaching the summing junction. The bottom path goes through a derivative gain block (K_d) and a summing junction. The input also goes through a derivative filter block (N) and then to this second summing junction. The output of the second summing junction goes through a filter block ($\frac{1}{s}$) and then to the main summing junction. The output of the main summing junction is the controller's output.

4.4 MULTI-AREA LFC

TIE-LINE

Diagram illustrating two areas connected by a line:

- Left Area: AREA-1
- Right Area: AREA -2

Fig:4.2diagram of a TIE-LINE

TIE-LINE permits the flow of power through more than one area.
Presentation of the tie-line introduces the tie-line power interchange error.

During the load in one zone changes, the electricity from another area is utilized through tie-line. This is called **TIE-LINE POWER EXCHANGE ERROR**. Thus, LFC likewise should control the tie-line power exchange error.

4.5 Simulation of two area systems

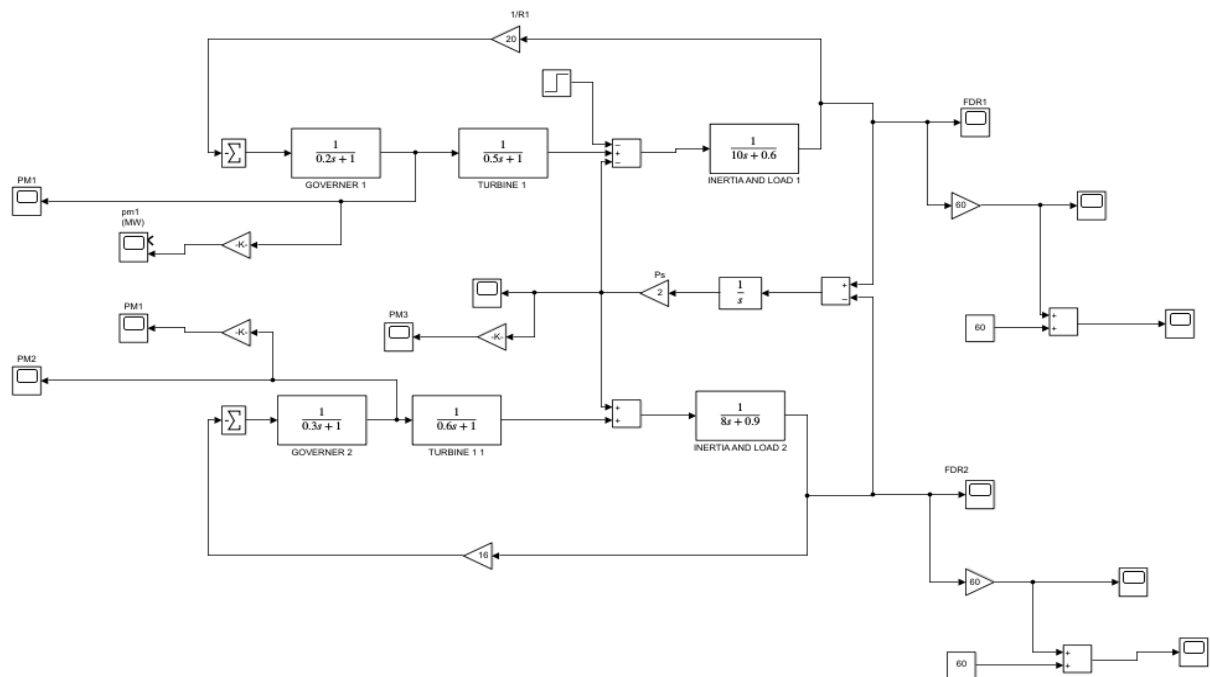


Fig 4.3: Simulation of two area systems

4.6 Simulation of three area systems

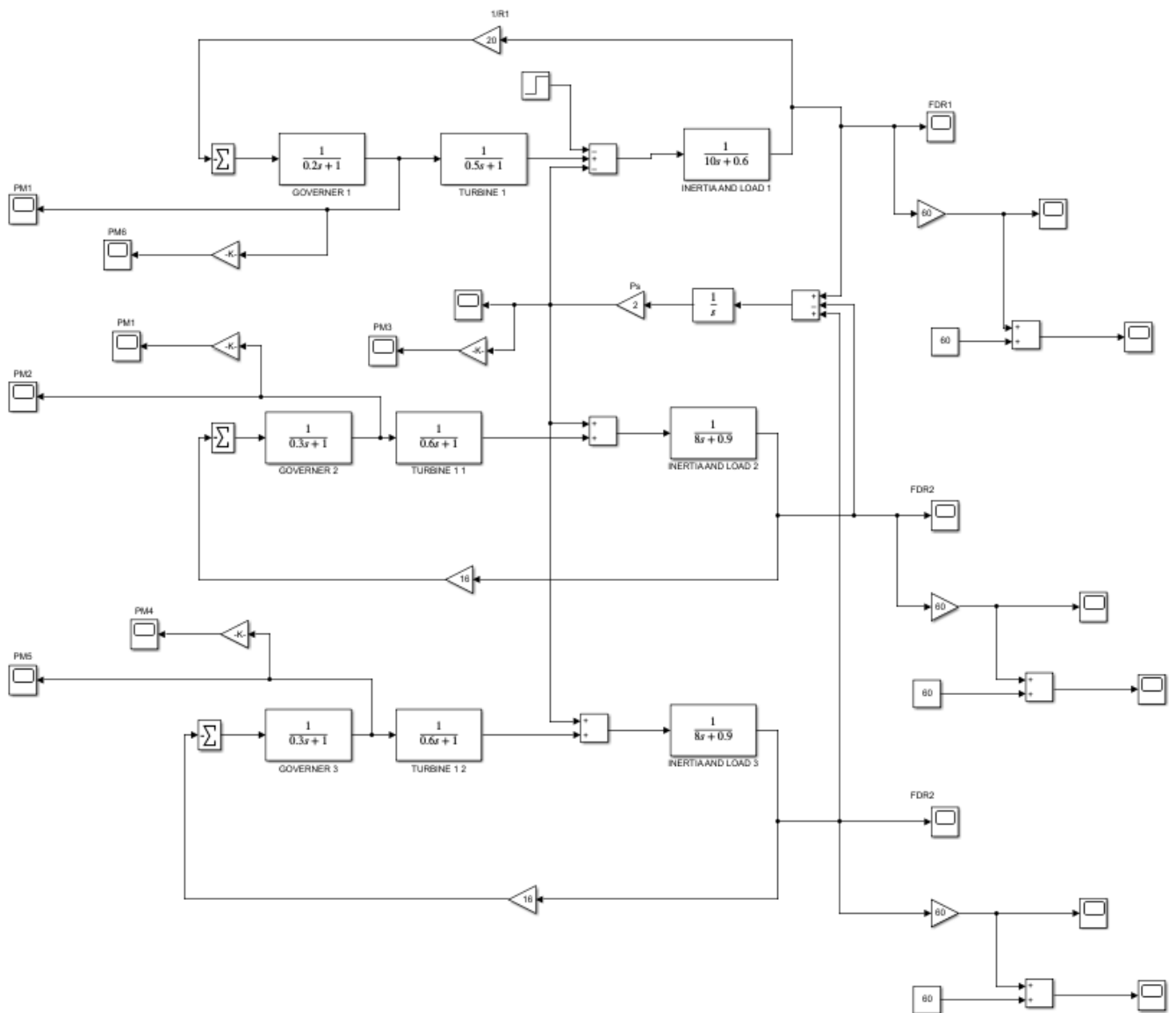


Fig 4.4: Simulation of three area systems

4.7 OPTIMIZATION

It helps the consumers to save money on their operating the system and to reduce the system losses.

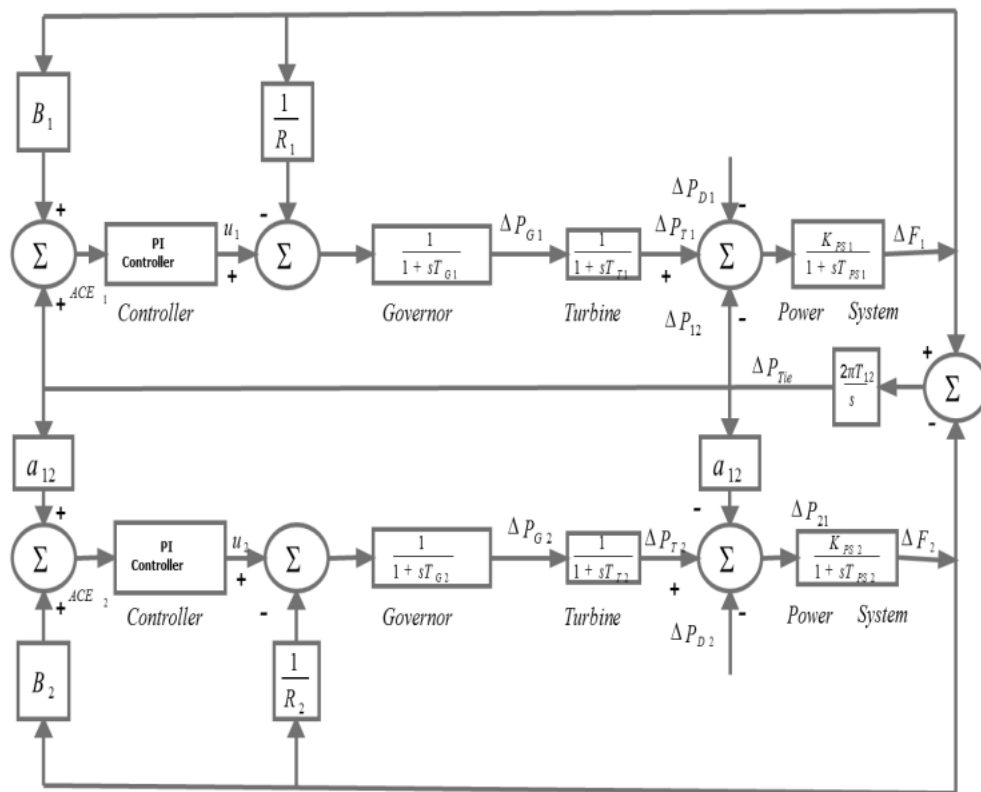


Fig 4.5 Circuit diagram of Multi-area connected system.

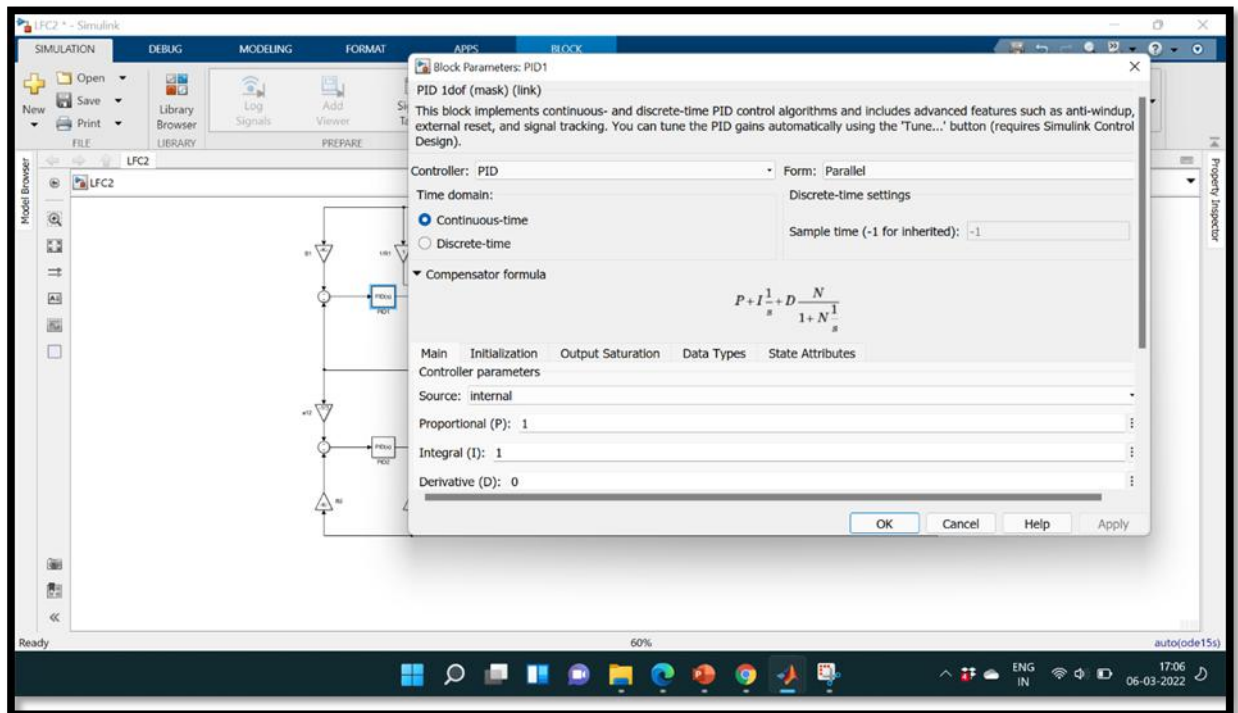


Fig:4.7-PID values of AREA-1

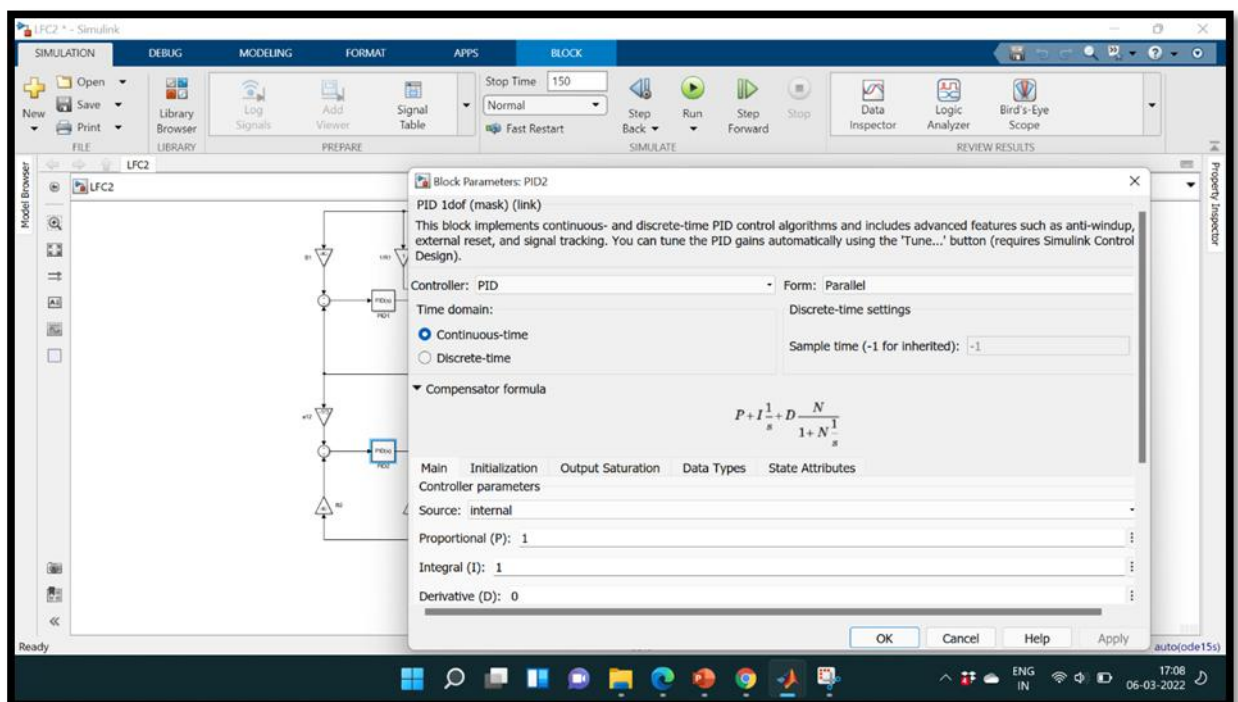


Fig:4.8-PID values of AREA-2

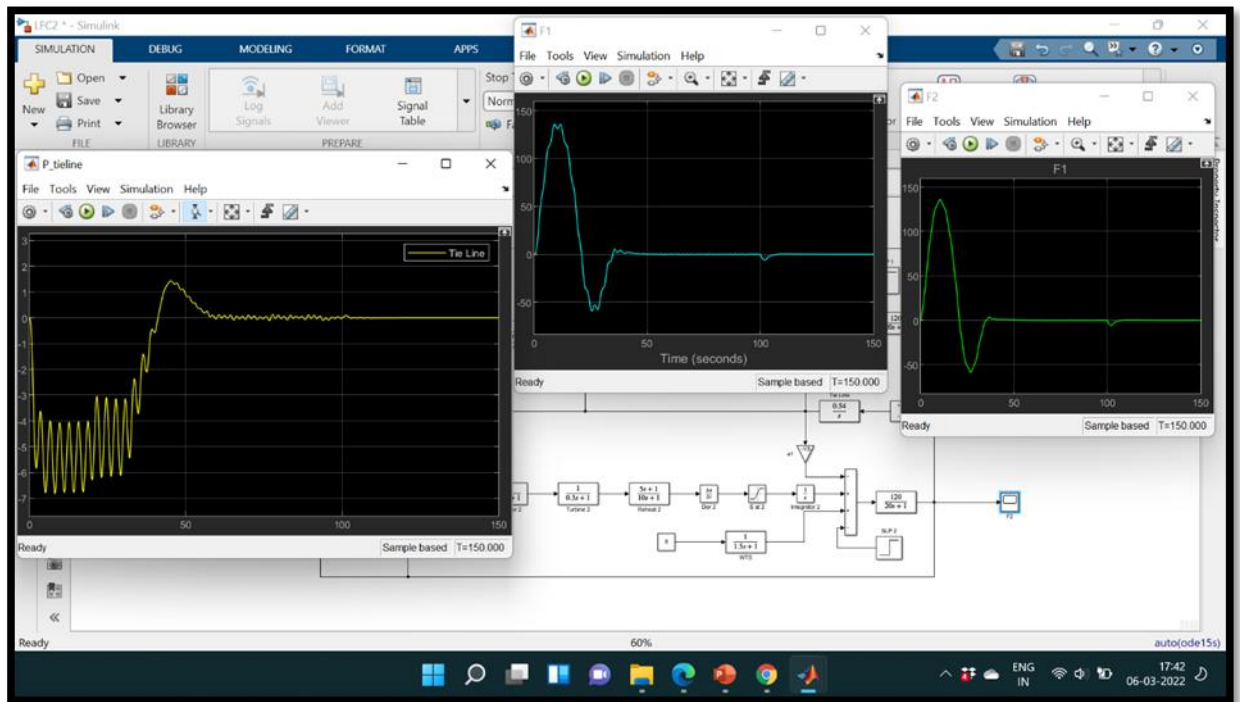


Fig-4.9 Simulation result for MANUAL OPTIMIZATION.

Chapter 5

OPTIMIZATIONALGORITHMS AND RESULTS

From Manual optimization, we observed that it takes a lot of time and it's not an effective way to optimize frequency and reduce the fluctuations.

To keep all these requirements in mind,we are going for advanced technologies which include optimization algorithms through natural processes.

In this chapter,we discuss different types of optimizations and their comparisons using renewable energies.

5.1 TYPES OF OPTIMIZATIONS:

1. GENETIC ALGORITHM.
2. CHAOTIC OPTIMIZATION.
3. FUZZY LOGIC OPTIMIZATION.
4. PARTICLE SWARM OPTIMIZATION ALOGRTHIM (PSO).

5.1.1GENETICALGORITHM :

GENETIC ALGORITHMwas broughtby**Dr.JOHN HOLLAND** and his peers.This method is the most efficient and flexibleusing in optimization observant and resolving problems. It's similar to the genetic process of biological organisms. In a populaceeach competes with everyone foodstuffs, the roof also attractsthe partner.Separate persons who arevictorious in pull throughas well as attracting partnersgoing tohave huge children. Ifheredity of one partneris suitable the individual will present in a generation after generation.It can be hand down in multi tasksidentical figureidentifying andresemblance processing.

This method is aeffective technique and handleslarge areas of problems that are hard for other techniques. This ismore effectivein finding possible solutions to that problem in short period.

AREA - 1			AREA- 2		
K_p	K_i	K_d	K_p	K_i	K_d
0.6003	0.6204	0.5224	0.3000	0.7319	0.3654

Table:5.1-PID values of both areas of genetic algorithm

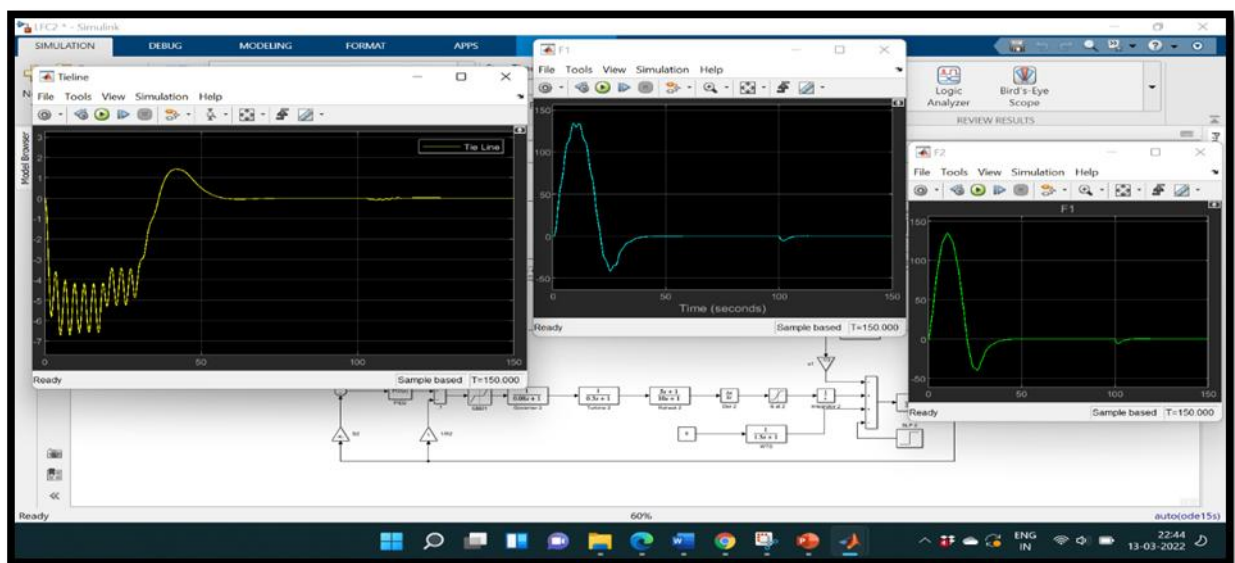


Fig:5.1-Simulation in MATLAB of GENETIC ALGORITHM

ADVANTAGES:

- Multi-dimensional, non-continuous problems are solved by this method
- This method can easily win the simulations and models in matlab.

Disadvantages:

- There is no surety that its worldwide optimal.
- The speed is low.

The aim of AGC is to manage the electric output of power generation within the zone in the reaction to changing the frequency, to maintain a sustained frequency, and to exchange with other areas within given limitation.

Thus, we are proposing PID optimized by **LCOA** to solve LFC.

5.1.2 CHAOTIC OPTIMIZATION:

Bounded unstable dynamic behaviour is called as **CHAOS**, which shows weak dependence on starting rules which include periodic motions are unsteady.

The tuning of PID gains is the best idea to preventing early local convergence is a good idea.

It carries out overall searches at a higher speed

The LCOA.

$$G_{PID}(s) = \frac{U(s)}{E(s)} = K_p + K_i s + \frac{K_d}{s} \quad (1)$$

$$G_{PID}(s) = K_p \left(1 + \frac{1}{T_i s} + T_d s \right) \quad (2)$$

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt} \quad (3)$$

$$y_1(k) = 1 - a|y_1(k-1)| + y(k-1) \quad (4)$$

$$y(k) = b y_1(k-1) \quad (5)$$

$$z(k) = \frac{y(k) - \alpha}{\beta - \alpha} \quad (6)$$

1: Initialise the variables at beginning state:

Given“(k= 1, y1(0), y(0), a =1.7and b = 0.5)”for the LOZI-MAP

Give the best objective function ($f^* = +\infty$)

2: Global search

```
Begin
  While  $k \leq M_g$  do
     $x_i(k) = L_i + z_i(k) \cdot (U_i - L_i) \quad i=1, \dots, n$ 
    If  $f(X(k)) < f^*$  Then
       $X^* = X(k)$ 
       $f^* = f(X(k))$ 
    End if
     $k = k + 1$ 
  End while
End
```

3: Chaos search Algorithm

Begin

While $k \leq M_g + M_l$ do

For $i=1$ to n

If $r < 0.5$ Then (Where r is a uniformly distributed random variable with range $[0, 1]$)

$$x_i(k) = x_i^* + \lambda_i z_i(k) \cdot |U_i - x_i^*|$$

Else if

$$x_i(k) = x_i^* - \lambda_i z_i(k) \cdot |x_i^* - L_i|$$

End if

End for

If $f(X(k)) < f^*$ Then

$$X^* = X(k)$$

$$f^* = f(X(k))$$

End if

$$k = k + 1$$

End while

End

AREA- 1			AREA - 2		
K_p	K_i	K_d	K_p	K_i	K_d
0.9390	0.7998	0.5636	0.5208	0.4775	0.7088

Table:5.2 PID values of area-1 and area-2 for CHAOTIC OPTIMIZATION

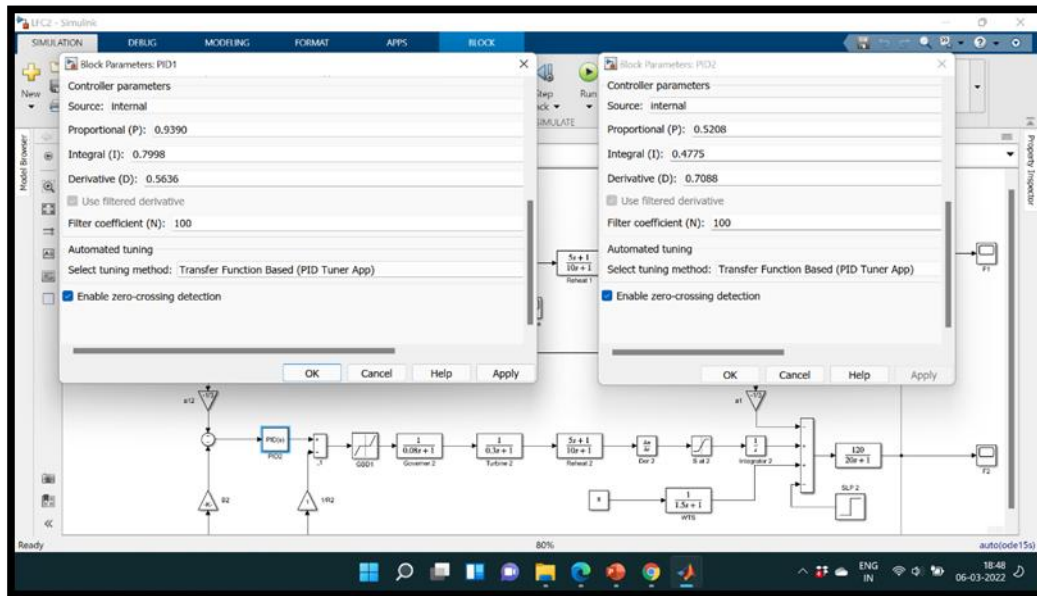


Fig:5.2

AREA-1and AREA-2 PID values of chaotic optimization simulation

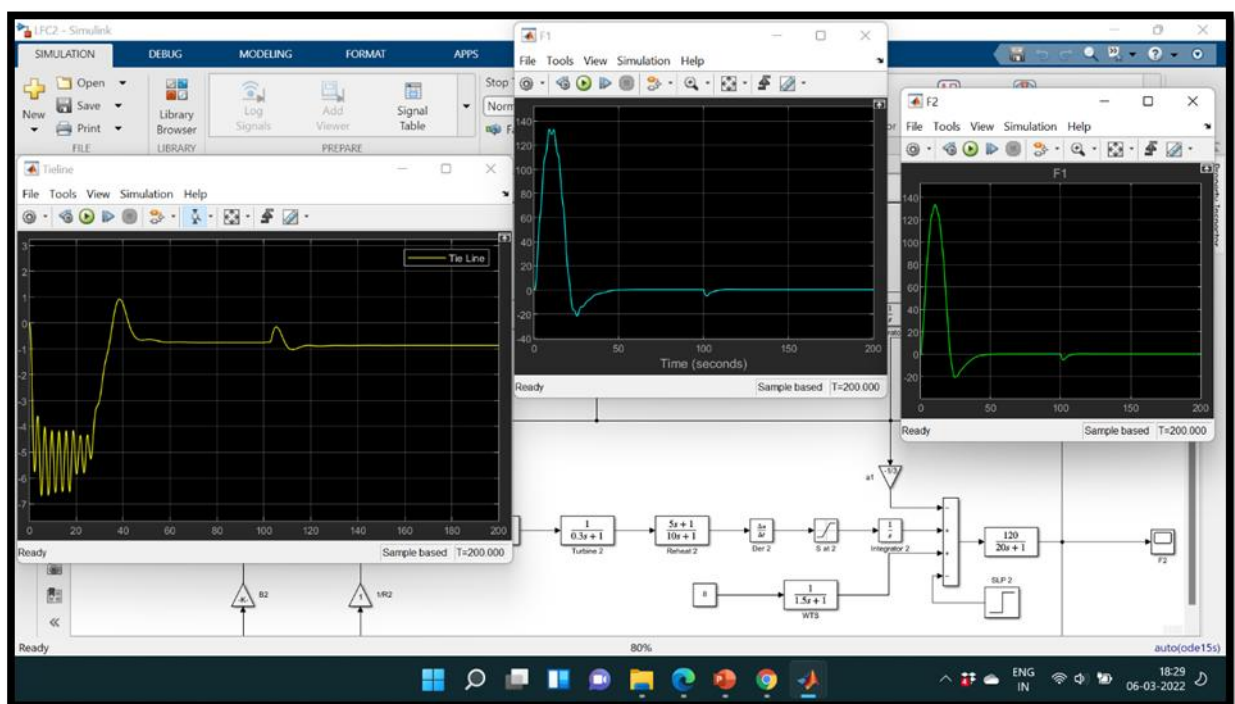


Fig:5.3 Simulation output of LCOA

From the above LCOA is used to maintain the bestgain values of the PID controller in LFC situation.

The above MATLAB simulation output are effective of LCOA and it reduces costs, after using the LCOA method the frequency of the disturbance is having **minimum overshoot and oscillations**.

The result shows the PID controller is capable to **ensure robust stability**, performing better results in wide range load changes.

5.1.3 FUZZY LOGIC OPTIMIZATION:

FLC is an **BEST METHOD** found by **Dr. LOTFI ZADEH**, as a control methodology

For attune the **IDEAL** values of the PID controller specifications, we bring forward to utilize the **FLO METHOD**.

The primary objective of FUZZY LOGIC is to **REDUCE** the fluctuations the output frequency and tie-line flow.

Nowadays one of the best methods that meet industrial needs is FUZZY LOGIC, because of

- Simplicity
- Robustness
- Used in all sciences and technologies
- Mostly in Power system control operations

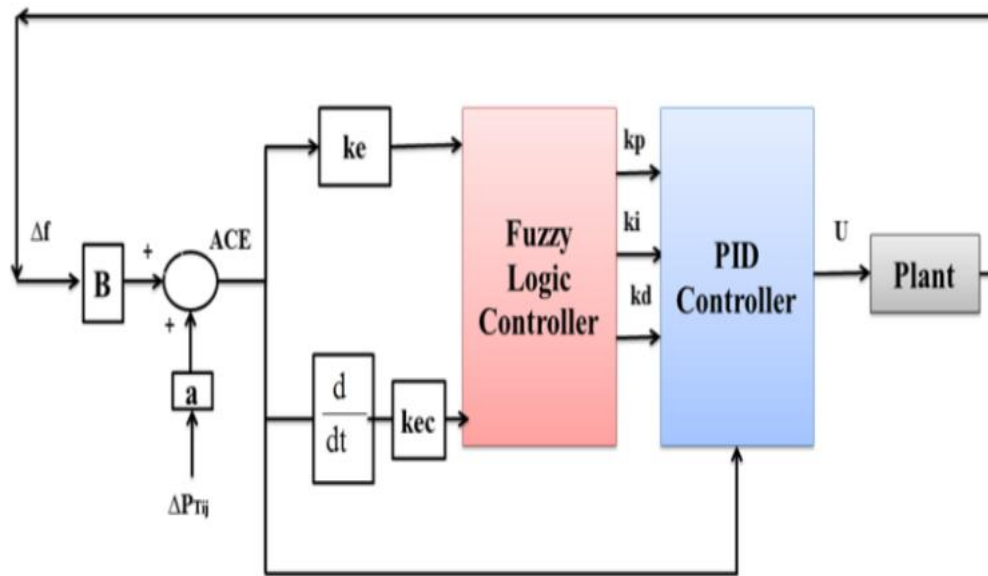


Fig:5.4-Basic structure of FLC

For the LFC, the load of the FLO are the $(ACE)/(dACE)$, and the output is K_p , K_i , K_d are predetermined as per the rules of the FC (Fuzzy controller).

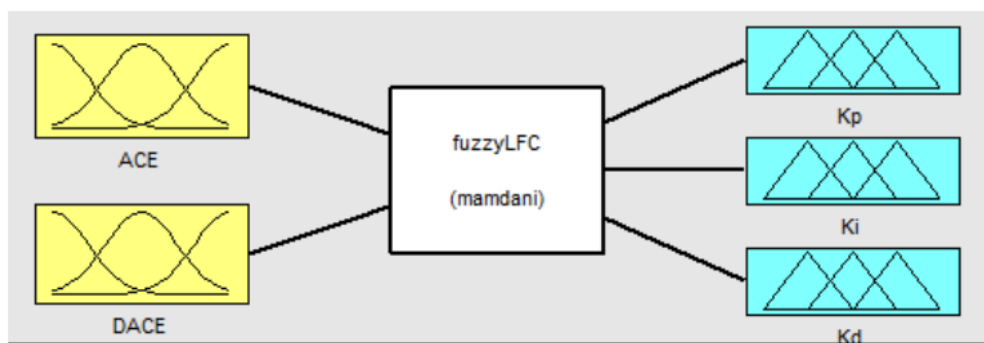


Fig:5.5- FLCInputs/outputs

dACE ACE	NB	NS	ZE	PS	PB
NB	PB	PB	PB	PB	PS
NS	PB	PM	PM	PB	PB
ZE	PB	PM	ZE	PB	PB
PS	PB	PM	PM	PM	PB
PB	PS	PB	PM	PM	PB

Table:5.2The above is the control rules used for fuzzy logic

K_p	K_d	K_i
3	1.665	3.2833

Table:5.3FUZZY LOGIC CONTROLLER PARAMETER

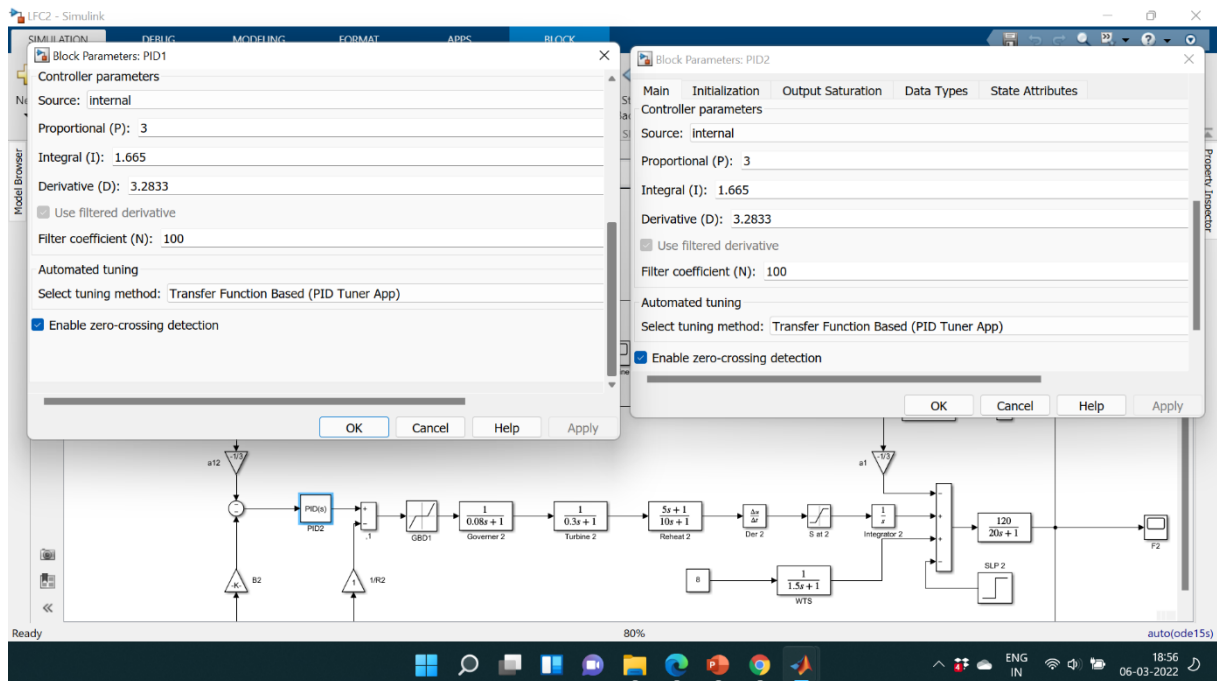


Fig:5.6-PID values of MULTI-AREA of Fuzzy logic controller input

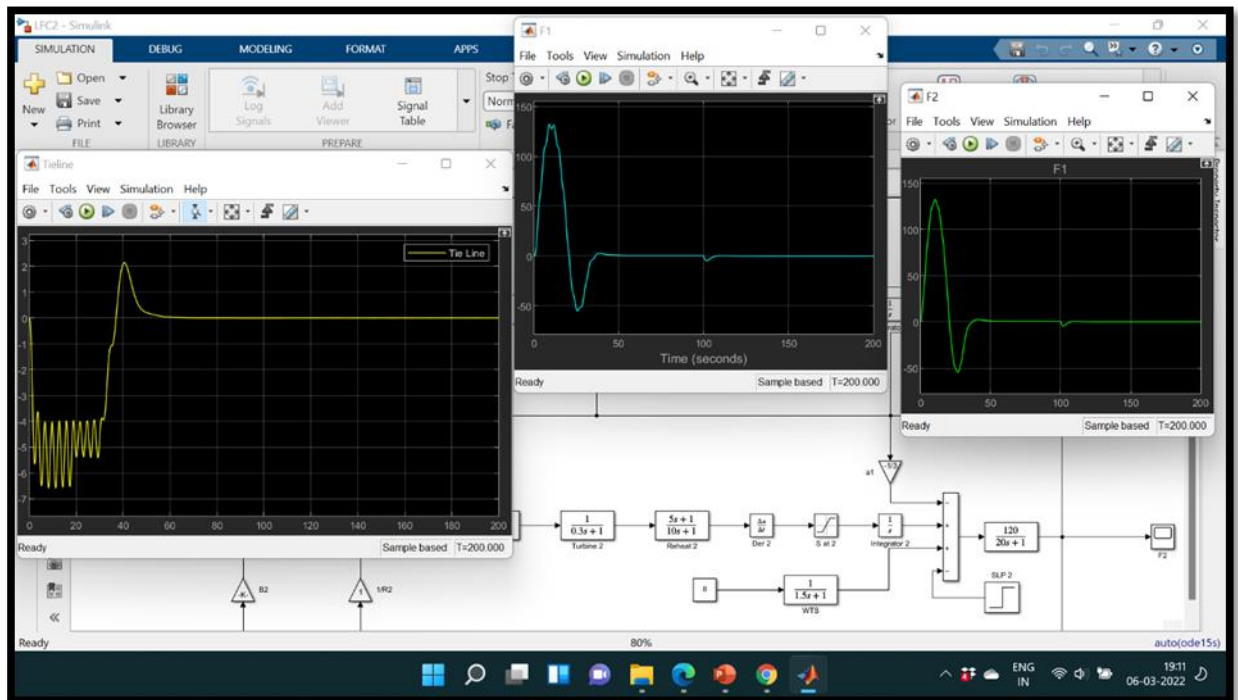


Fig:5.7:Simulation of FUZZY LOGIC CONTROLLER OUTPUT

With ideal PID guideline, the frequency variation of the network frequency and tie-line power passage are efficiently reduced.

From above all the optimization FUZZY LOGIC CONTROLLER IS MOST EFFICIENT and fast.

Chapter 6

CONCLUSION AND FUTURE WORK

Conclusion

Controlling the power system to meet the customer requirement is a demanding duty that inspired to design ideal controller. Ability to monitor the power system like keeping up with frequency and voltage in no time. In our project FLC is utilised to tune PID parameters. A multi area system is taken into count to prove as its most efficient method than GA and LCOA, **THE variations OF THE SYSTEM FREQUENCY AND TIE-LINE POWER FLOW ARE EFFECTIVLY SUPPRESSED.**

Future work

Our future work consists of the following given topics:

- (a) To optimize the parameters to obtain stability at an earlier stage.
- (b) To implement the power grid using renewable energy sources.
- (c) To optimize frequency using the PARTICLE SWARM OPTIMIZATION (PSO) method.

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