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Load Frequency Control using PSO of Multi Area system

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A B S T R A C T

The backbone of electrical distribution is power systems. In nature, power systems are interrelated. Several separate areas are linked together to form a larger system known as the multi-area system. Power system disturbances such as load shift, short circuit, and open circuit occur from time to time in the system. In this system, any of these disruptions creates a deviation in the system frequency. Electrical equipment used in daily life is heavily reliant on system frequency. Any change in frequency affects the equipment and causes the entire system to malfunction. This paper discusses the issue of load frequency regulation in power networks. Load Frequency Control is critical in power systems for ensuring safe and reliable power delivery. Load Frequency Control (LFC) rebalances generation and end-load demand. This causes the system frequency to stabilize. The designs of several controllers in this thesis provide a solution to this challenge. Work is being done to improve the reaction time for Load Frequency Control. Traditional PID controllers and Particle Swarm Optimization-based controllers are utilized in this work to investigate Load Frequency Control in Multi-area Power Systems. It demonstrates the efficacy of employing these controllers for Load Frequency Control. The frequency of the system is stabilized by the use of these controls. In this work, controllers were utilized to determine the system reaction to a disruption in multi-area systems. The outcomes acquired by various controllers are compared, and a conclusion is reached at the end.

Keywords: Load Frequency control, PID, PSO, Four area power system

1. INTRODUCTION

Power Systems are the linking of numerous control domains. Tie-lines join them. Any disruption in these control areas can cause the frequency to differ from its typical value. For Power Systems to function properly, the frequency must be kept constant. Load Frequency Control helps to keep this going. Load Frequency Control is the method of adjusting the real power output of the producing unit in the case of a disturbance by changing the frequency of the system. Disturbance might occur from any direction. It could be in the creating or loading parts. Disturbance can also be caused by a problem in another sector of the power system. This keeps the frequency in India at 50Hz. In India, the recommended frequency is 50Hz. It varies depending on where you are in the world. It is 60Hz, just like in the United States.

Disturbances in any other element of the network that is connected to the existing power system network have an influence on the frequency of the entire network. For example, if two areas are linked and one of the internal faults occurs in area one, the turbine is tripped and generation from area one ceases to operate. This reduces the system's network frequency. If the lost power production in area 1 is not recovered by increasing the generated power in area 2, the frequency protection in area 2 will be engaged and will trip the unit that is causing the loss of generation in either of the two units. Similar reactions will occur if these two defined areas are well related to any of the other places. The ability of a power system to maintain a steady state frequency in any acceptable range (for example, 0.5%) defines frequency stability in any system. It is mostly dependent on the capacity to maintain a balance between generated electricity and end-user load demand.

A linked power system requires a match in total generation to total load demand and its associated system losses for successful functioning. The load is highly volatile in its basic nature, which negatively impacts the system frequency, therefore controlling the electricity generation has become increasingly crucial in today's environment of increasing load demand and decreasing generation means. The growth in load demands poses very serious concerns to the reliability of the power system network. Maintaining a steady frequency in the power system is critical for the health of the power equipment and other utilization equipment on the other end of the consumers. To keep the frequency within a given range, it is critical to maintain a real-time balance between demand and supply.

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Load frequency control is a critical issue in power systems. It ensures a dependable and secure power supply to end users. The following are the objectives of load frequency control:

1. To ensure that there is no power deviation in steady state following a system disruption.
2. To reduce the electricity flow between surrounding locations via tie-lines.
3. Maintaining appropriate levels of frequency and power deviation excess and undershoot.
4. To maintain the shortest possible settling time for frequency variations.

The need for electricity is increasing in today's society. To improve the reliability of power delivery to customers, multiple power system areas must be linked together so that they can exchange power as needed. There is also a new smart grid concept. Renewable energy sectors are linked to conventional energy areas in smart networks. These sophisticated ideas about our future power network have resulted in non-linearity and tremendous system complexity. Previously, when there was no idea of power system network interconnections, standard methods of control such as PID control were suitable for controlling load frequency. However, as complexity and nonlinearity increase, new methods are being offered. These technologies are based on artificial intelligence and are capable of making automatic judgments in the face of changes in load or disruptions in the power system network. This has allowed for faster detection of disruptions and more effective control in a shorter period of time.

1.1 Objective of Dissertation

The main objective of this work is:

1. To create a two, three, and four area system in MATLAB/Simulink using different power system areas.
2. To use a PID controller to stabilize frequency variations caused by disturbances.
3. Finally, a PSO-based PID controller is used to stabilize frequency variations caused by disturbances.

1.2 Load Frequency Control in Single Area Systems

In a single area system, there are no connections between areas. As a result, no problems with power exchange between two power systems exist. The primary purpose of single-area power systems is to maintain the desired system frequency. Constant frequency is maintained in a single area network by using an integrator as a reference for the governor units. This integral component assures zero frequency error in the steady-state condition.
Block diagram for load frequency control in single area system is given below.

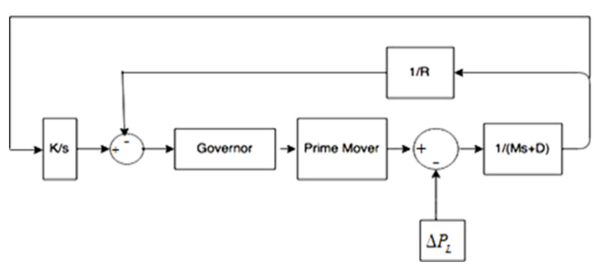

Figure Error! No text of specified style in document.**.1 Loadfrequencycontrol insingleareasystem**

1.3 Load Frequency Control in Multi-Area Systems

The generated power should match the end load demand power for successful power and frequency control in a multi-area network. The nature of the load changes in nature, causing the system frequency to change at all times. It has a negative impact on the operation of electricity systems.
There are two quantities on which the emphasis remains in a single area network. The first is a change in frequency, while the second is a change in tie-line power exchanges. These two variables are combined to generate a new phrase known as the ACE. The following equation defines ACE.

$$ACE_i=\Delta P_{12}+b_i\Delta f_i$$

Eqn. **Error! No text of specified style in document.**.1

Here,
ACE=Area Control Error of ith area
ΔP_{12}=changed in tie-line power between area 1 and area 2
b_i = frequency bias constant of ith area
Δf_i= frequency deviation of ith area
Multi-area systems are the interconnection of two or more areas with the help of tie-lines. Generalized block diagram of a two-area network is given in the below figure.

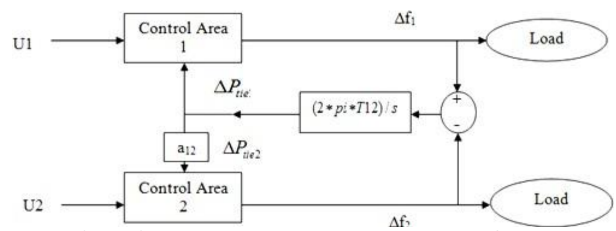

Figure Error! No text of specified style in document.**.2 Blockdiagramof generalizedtwoareasystem**

The generators in a multi-area system are expected to be in synchronism. Load deviation in any of the control areas causes frequency deviation throughout the area as well as a change in tie-line power deviation between different areas of the network. This variation in frequency is insignificant, but it must be corrected as soon as possible. Tie-lines connect various regions of the system to one another. If the frequency of the area is not the same, power exchange occurs in the system via the tie-lines. The tie-line layout in any two-area scheme is depicted below.

$$\Delta P_{tie,ij} = \frac{1}{s} T_{ij}[\Delta F_i(s) - \Delta F_j(s)]$$

Eqn. **Error! No text of specified style in document.**.2

Where,
$\Delta Ptie,$ = tie-line power exchange between area 1 and area 2
Tij= tie-line synchronization torque co-efficient
This equation can be shown in a model as shown below.

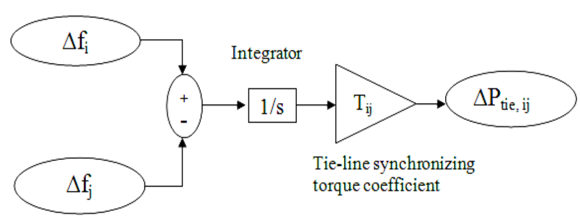

Figure Error! No text of specified style in document.**.3 twoareatie-line model**

1.4 Particle Swarm Optimization

PSO optimization is one of the most effective LFC optimization techniques. It was created in 1995 and is based on bird flocking and fish schooling mapping. It is dependent on the swarms' population. For optimization tasks, it requires extremely little computational time and memory. Bird flocking is a technique that is based on how birds go in search of food. They take the shortest route to their goal. The population of swarms is randomly produced in this technique, and the optimal solution in their position is determined using the fitness value. The global value is another excellent option. The particle's position is changed to its best value at the end of each cycle. Every iteration, the particles' velocity is updated.

2. RESEARCH METHODOLOGY

The following steps provide a step-by-step proposed methodology for Load frequency control of a multi- area power system:

1. **Establish the desired frequency:** Before any control action can be conducted, the system's desired frequency must be determined. The electricity system operator or engineer normally sets this to 50 or 60 Hz.
2. **Establish the desired tie-line power exchanges:** It is also necessary to establish the desired tie-line power exchanges. This is the quantity of power that will be transferred between the various parts of the system.
3. **Calculate the current frequency and tie-line power exchanges:** After that, the current frequency and tie-line power exchanges must be determined. This can be accomplished by monitoring the system or by employing mathematical models.
4. **Determine the necessary control action:** After determining the current frequency and tie-line power exchanges, the relevant control action must be determined. This is accomplished by comparing the desired frequency and power exchanges to the current ones.
5. **Adjust the generation and/or load:** If the current frequency and tie-line power exchanges are not equal, the generation and/or load must be changed. This can be accomplished by increasing or decreasing the system's generation and/or load.
6. **Monitor the system:** Following that, the system must be monitored to ensure that the appropriate frequency and tie-line power exchanges are achieved. This can be accomplished by either monitoring frequency and tie-line power exchanges or by employing mathematical models.
7. The particle swarm optimization (PSO) algorithm can be used to control the load frequency control (LFC) of a multi-area system. The PSO method is an evolutionary optimization technique based on a group of particles' collective behavior. Each particle in the swarm represents a

potential solution to the problem, and the swarm's behavior is dictated by the particles' interactions with one another and with the environment. The iterative technique is based on the concept of a global best solution that is constantly updated by the particles. Each particle in the swarm adjusts its velocity and position to move towards the global optimal solution.

8. The PSO algorithm can be used to optimize the parameters of a multi-area LFC controller. The parameters may include the integral and proportional controller gains, setpoints, and time constants. The particles in the swarm then alter the parameters based on the global best solution.
9. Using the PSO technique, you can create an optimal LFC controller for a multi-area system. The algorithm is capable of optimizing the controller parameters to ensure that the system works within its optimal operating range.
10. Steps 4-6 must be repeated: The process of modifying the generation and/or load, as well as monitoring the system, must be repeated until the required frequency and tie-line power exchanges are achieved.

The power system operator or engineer can control the frequency and tie-line power exchanges in a multi-area power system, as well as maintain the system's generation and load balance. This will eventually result in a more efficient and dependable electricity system.

Here the research methodology is divided in to three section and compare their result of load frequency control using different manner.

1. Load Frequency Control without any Controller
2. Load Frequency control using PID Controller
3. Load Frequency Control using PSO Controller

2.1 Load Frequency Control Without Any Controller

In this section, we will investigate load frequency regulation on single and multi-area power systems using the MATLAB/SIMULINK model. Block diagrams are used to create a model of the power system. A unit step input is used to cause a disturbance in the system. The system responds to the unit step disruption, resulting in a change in frequency at the output. There is no controller in this area to compensate for the change in load. First, we will do a load control analysis on a single area, and then we will move on to multi-area systems.

2.2 Load Frequency Control Using Pid Controller

In this section, we will look at the components of the PID controller and how they can be used to analyze load frequency management in single and multi-area systems. PID controllers are widely employed in power system load frequency investigations. In this chapter, traditional I, PI, and PID controllers are utilized to control load frequency in single and multi-area systems. The results from these controllers will be utilized to study with the controllers that will be used in the following part.

2.3 PID Controller

PID controller is the combination of proportional, integral and derivative controllers in either series or parallel configuration. Equation of a normally used PID controller is

$$U_c(s) = \left[k_P + \frac{k_I}{s} + k_D s\right]E(s) \qquad \text{Eqn. 2.1}$$

Structure of the PID controller used in the work as given in the Fig 2.1 below.

In the various parts of the PID controller are discussed in brief.

Proportional gain (Kp): A higher proportional gain value in the PID controller results in a faster system response. A higher value of this gain, on the other hand, can promote system instability and prolong oscillations. In the system, this is highly undesirable. As a result, it is critical to select the proportional gain amount properly.

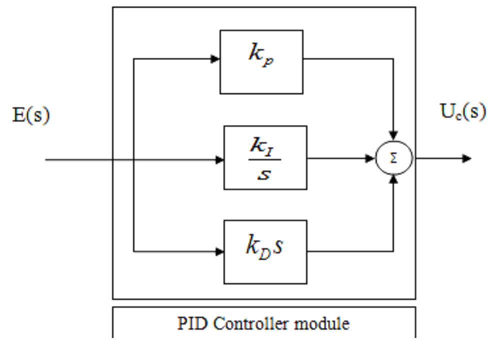

Figure 2.1 PID controllerblockdiagram

Integral gain (Ki): This controller's high value produces high steady-state faults. This controller is designed to lower the system's steady-state inaccuracy. This controller is utilized in this project both alone and in conjunction with the PI and PID controllers. This demonstrates its usefulness in lowering the system's steady-state inaccuracy.

Derivative gain (Kd): Large value of this controller decreases overshoot in the system. This makes the system respond faster to the incoming disturbances to the system.

2.4 PID Tuning Method

The Ziegler-Nichols method is used for tuning. Among the most well-known closed loop tuning approaches is the Ziegler-Nichols continuous cycling method. This is a manual tuning procedure. After a tiny step change or disturbance, the controller's gain is gradually modified (increased or lowered) until the process output constantly cycles. The table below shows how to calculate PID parameters:

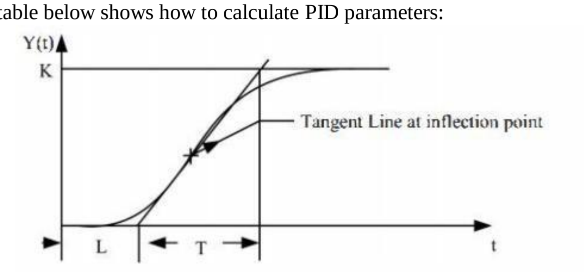

Figure 2.2 Ziegler-Nicholsmethod

Table 2.1 Ziegler-NicholsMethod

Controller		**Kp**	**Ti**	**Td**
Ziegler-Nichols Method (Closedloop)	**P**	**T/L**	**-**	**-**
	PI	**0.9T/L**	**L/0.3**	**-**
	PID	**1.2T/L**	**2L**	**0.5L**

3. RESULT AND DISCUSSION

In this section, we will investigate load frequency regulation on single and multi-area power systems using the MATLAB/SIMULINK model. Block diagrams are used to create a model of the power system. A unit step input is used to cause a disturbance in the system. The system responds to the unit step disruption, resulting in a change in frequency at the output. There is no controller in this area to compensate for the change in load. First, we will do a load control analysis on a single area, and then we will move on to multi-area systems.

3.1 Single Area System

The properties of a single area network are quite simple and straightforward. This allows us to investigate more sophisticated multi-area networks. In the next sections, we will describe numerous single-area networks.

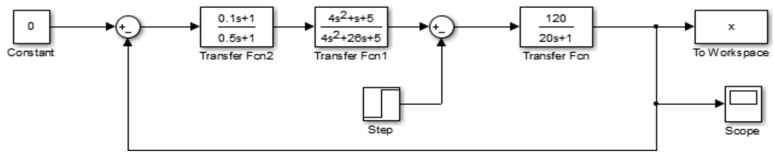

Figure 3.1 Single area hydro system with governor

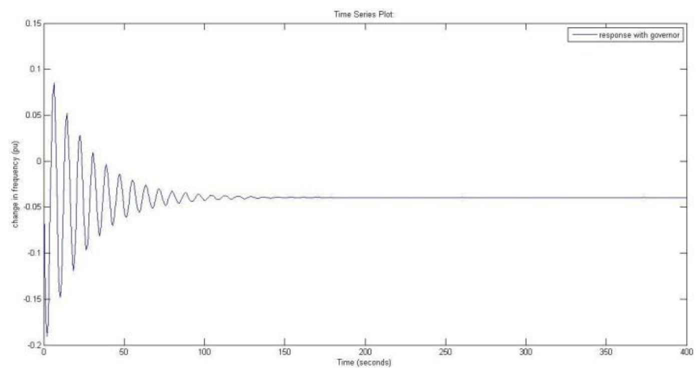

Figure 3.2 Response of a single area hydro system with generator

According to the foregoing findings, the governor is critical to the stability of LFC. Using input, the governor assists the system in settling down to zero.In the preceding section, it was noted that the system's reaction improved when a governor was present in the system. The latter part of this section will go over multi-area systems.

3.2 Multi-Area Systems

Any fluctuations in a two-area system should be handled by the generators in both regions. Furthermore, the tie-line power change should be set to zero. This is accomplished by employing an integrator, which integrates power from the tie-line and feeds it back to the governors. We use the word ACE to describe this. ACE is an abbreviation for Area Control Error. It is the result of a combination of incremental frequency and tie-line power change.

ACE is defined as

$ACEi = Pi + bi\Delta fi$ Eqn. 3.1

Where,

b_i = biasing factor

Δf_i = change in frequency of area1

In two area system there are two areas dependent on each other. Thus, the ACE for a two-area system can be defined as given below.

ACE for area 1 is given by,

$ACE_1(s) = P_1(s) + b_1\Delta f_1(s)$ Eqn. 3.2

ACE for area 2 is given by,

$ACE_2(s) = P_2(s) + b_2\Delta f_2(s)$ Eqn. 3.3

Similarly, equations can be made for three and four area systems.

3.3 Load Frequency Control Using Pid Controller

PID controller in two area system

The previous chapter examined the performance of a single area system. It was determined that the governor is required for frequency stabilization. In this section, you will learn how to utilize a PID controller to stabilize frequency in two, three, and four area systems. The graph below depicts the influence of PID controllers in a two-area system.

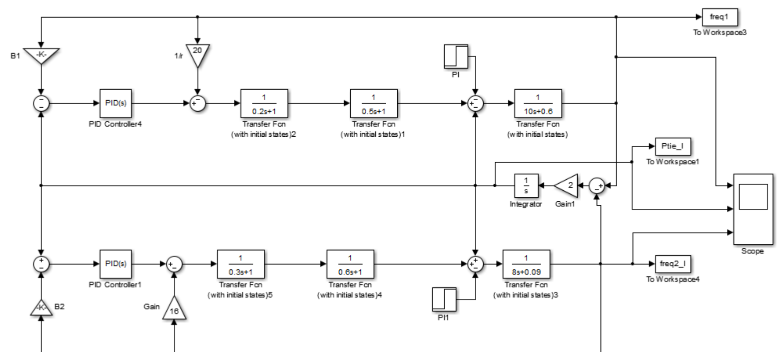

Figure 3.3 PID controllerintwoareasystem

Response of the two-area thermal system with I, PI and PID controllers is shown in the figures below.

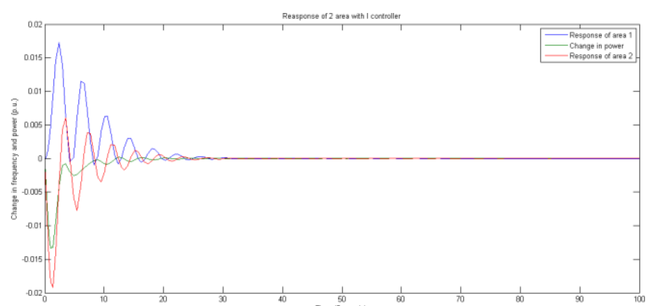

Figure 3.4 Response oftwoareasystemwithIcontroller

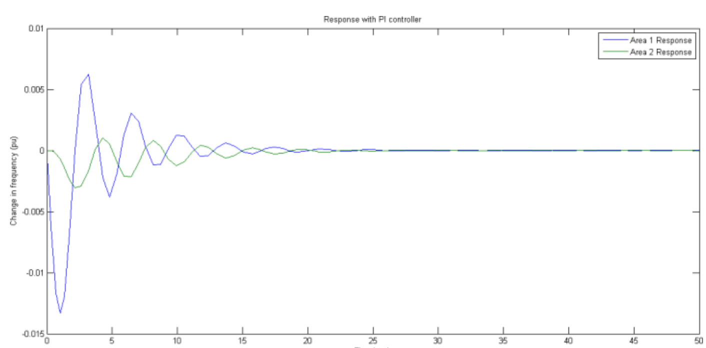

Figure3.5Response oftwoareasystemwith PIcontroller

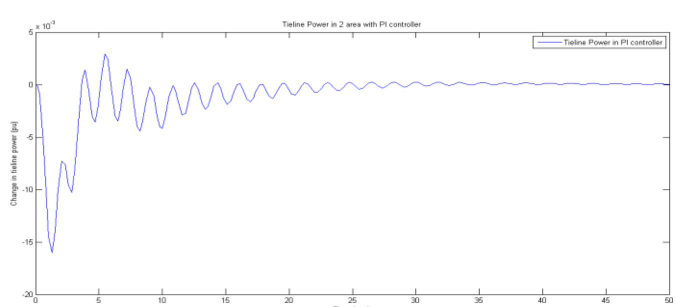

Figure3.6 Tie-linepowerintwoareasystemwith PIcontroller

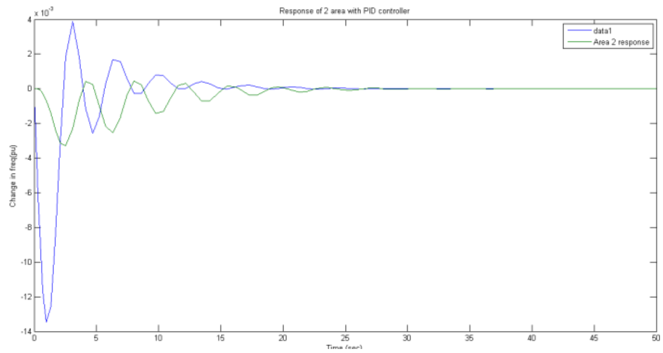

Figure3.7 Response oftwo areasystemwith PID controller

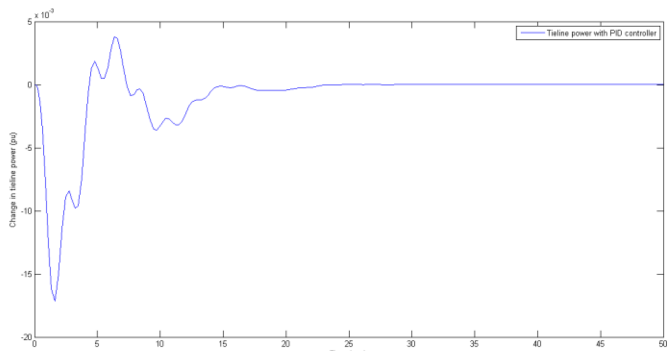

Figure3.8 Tie-line power with PID controller

Table 3.1 given below shows the response with the PID controllers in the two-area thermal system.

Table3.1 Area-wiseresponseoftwo areasystem

Controller	Settling time (inseconds)		Overshoot(inp.u.)		Undershoot (inp.u.)		Tieline power (inp.u.)
	Area1	Area2	Area1	Area2	Area1	Area2	Onsteadystat e
I	32	31	0.017	0.007	0.01	0.019	30
PI	25	25	0.006	0.002	0.013	0.002	38
PID	22	25	0.004	0.001	0.013	0.002	25

3.4 PID controller in four-area system

This section will look into LFC in a four-area scheme. The MATLAB model of a four-area system is shown in the image below. The response of the four-area system with PID controller is depicted in the picture below.

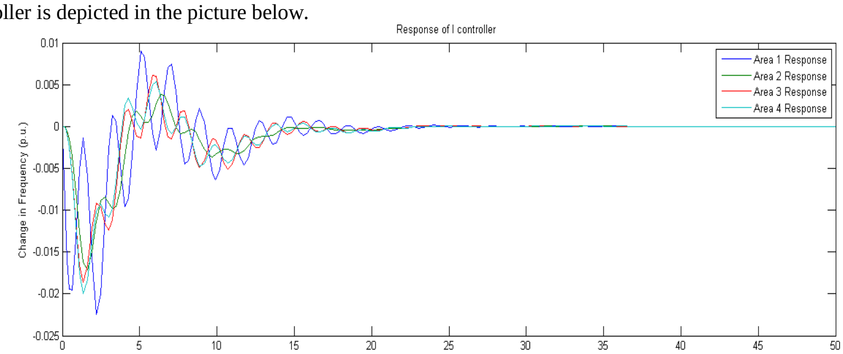

Figure3.9 Responseoffourareasystem withIcontroller

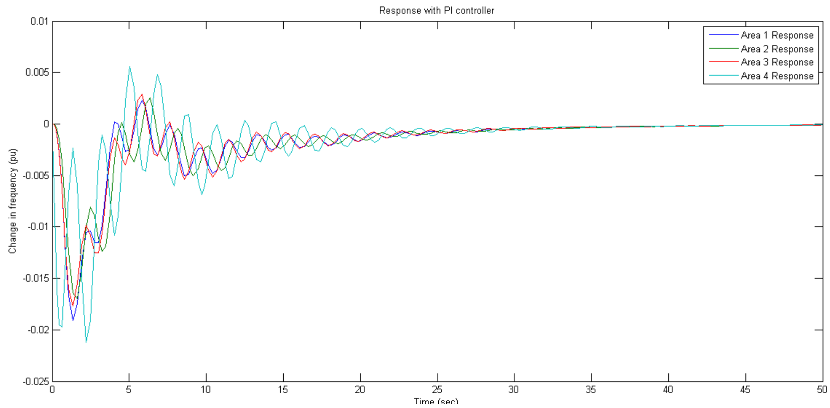

Figure3.10 Response of four area system with PI controller

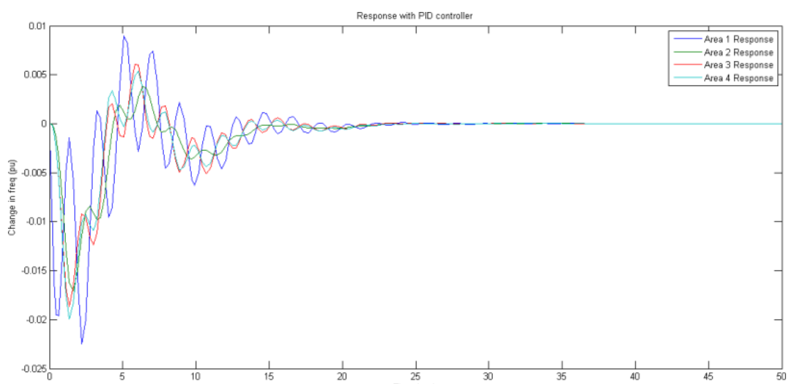

Figure3.11 Response of four area system with PID controller

Table3.2 Area-wise response of four area system

Controller	**Settlingtime(inseconds)**				**Overshoot(in p.u.)**				**Undershoot(in p.u.)**			
	Area 1	Area 2	Area 3	Area 4	Area 1	Area 2	Area 3	Area 4	Area 1	Area 2	Area 3	Area 4
I	30	31	32	31	0.009	0.004	0.005	0.004	-0.022	-0.017	-0.017	-0.02
PI	35	37	38	34	0.001	0.004	0.004	0.005	-0.02	-0.017	-0.017	-0.02
PID	25	26	26	25	0.008	0.005	0.006	0.005	-0.022	-0.017	-0.019	-0.02

According to the results, the PID controller outperforms the I and PI controllers in multi-area systems.

3.5 LFC Using Particle Swarm Optimization

LFC in two area system

In MATLAB/Simulink, a two-area scheme is used. It is depicted in the diagram below. The PSO method is applied to the system, and the PID parameter values are evaluated. These parameters are applied to the PID block, and the resulting reaction is shown in the following figure.

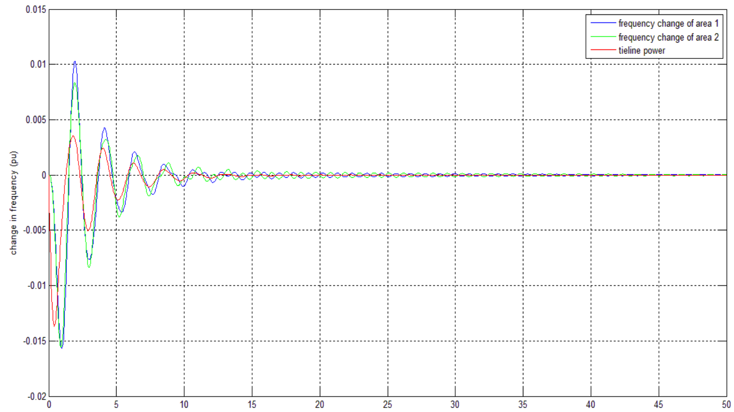

Figure 3.12 Response of two area system with PSO

Table 3.3 Response of two area system with PSO

Settling time (in seconds)		Overshoot (in p.u.)		Undershoot (in p.u.)	
Area1	**Area 2**	**Area 1**	**Area 2**	**Area1**	**Area 2**
13	14	0.01	0.008	-0.015	-0.015

LFC in four area system

MATLAB/Simulink employs a four-area scheme. It is depicted in the diagram below. The PSO method is applied to the system, and the PID parameter values are evaluated. These parameters are applied to the PID block, and the resulting reaction is shown in the following figure.

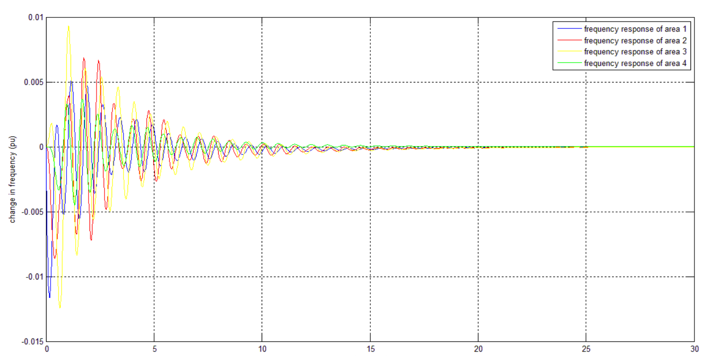

Figure 3.13 Response of four area system with PSO

Table 3.4 Response of four-area system with PSO

Settling time (in seconds)				Overshoot (in p.u.)				Undershoot (in p.u.)			
Area 1	Area 2	Area 3	Area 4	Area 1	Area 2	Area 3	Area 4	Area 1	Area 2	Area 3	Area 4
15	16	14	14	0.005	0.007	0.009	0.003	-0.012	-0.008	-0.013	- 0.004

The aforementioned data show that the PSO algorithm increases system performance in the event of a disturbance. It offers the best solution to the load frequency management problem.

4. CONCLUSIONS AND FUTURE SCOPE

4.1 Conclusions

This work contributes to the regulation of load frequency in a multi-area power system using conventional and intelligent controllers. PID controllers are traditional controllers, whereas PSO is an intelligent controller.

These controllers were utilized to control the load frequency in region 1 with disturbance. Thermal and hydroelectric power systems were used. The first PID controller was utilized with various I, PI, and PID values. When a PID controller was used as a controller in a multi-area system, the results were improved.

The result of settling time from traditional controller PID for Area 1 is 25 second, Overshoot 0.008 and undershoot -0.022 whereas 15 second, Overshoot 0.005 and undershoot -0.012 from PSO. The response of Area 2 is 26 second, Overshoot 0.006 and undershoot -0.017 whereas 16 second, Overshoot 0.005 and undershoot -0.008 from PSO. The response of Area 3 is 14 second, Overshoot 0.009 and undershoot -0.019 whereas 14 second, Overshoot 0.008 and undershoot -0.013 from PSO. The response of Area 4 is 25 second, Overshoot 0.005 and undershoot -0.02 whereas 14 second, Overshoot 0.003 and undershoot -0.004 from PSO.

The Particle Swarm Optimization approach was utilized to optimize the PID controller's parameters. The system performed best when the parameters were optimized. It was determined that PSO optimization outperformed the other controller.

4.2 Future Scope

Work done in this paper can be extended to following directions:

1. The created Fuzzy logic controller can be used in increasingly complicated systems to achieve optimal performance.
2. PSO can be combined with a fuzzy controller to produce better outcomes.
3. To achieve best results, LFC of renewable energy sources can be performed using the PSO algorithm.
4. PSO can be used to investigate load fluctuations in power systems.

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