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Frequency Control of two Area System using PSO

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A B S T R A C T

This work is a novel approach for frequency control of two-area systems using Particle Swarm Optimization (PSO). The proposed approach seeks to provide a cost-effective and efficient solution to the problem of controlling the power and frequency of two-area systems. The main components of the proposed approach are the frequency and power control of the two-area system, PSO algorithm, and simulation of the results. The frequency control of the two-area system is achieved through the use of a controller, which is designed using a PID controller. The PSO algorithm is used to optimize the parameters of the controller in order to achieve the desired frequency control of the two-area system. The performance of the proposed approach is evaluated using MATLAB/SIMULINK simulation. The result of LFC in terms of settling time from controller PID for Area 1 is 25 second, Overshoot value 0.004 per unit and undershoot 0.013 pe unit and Tieline power 25 whereas the settling time 13 second, Overshoot 0.01 per unit and undershoot -0.015 per unit from using PSO optimization. Similarly getting the response of LFC for Area 2 from PID is 25 second, Overshoot 0.001 per unit and undershoot 0.002 per unit whereas 14 second, Overshoot 0.008 per unit and undershoot -0.015 per unit from PSO optimization. The results improved when a PID controller was utilised as a controller in a two-area system. The Particle Swarm Optimisation method was used to optimize the parameters of the PID controller. When the parameters were optimized, the system performed best. PSO optimization was more effective than the PID controller for the both system single is as well as two area system.

Keywords:Load Frequency control, PID, PSO

1. Introduction

Particle Swarm Optimisation (PSO) for frequency management of two area systems is a prominent method in the power system sector for optimising the frequency control of two areas. The PSO algorithm has been employed in a variety of power system applications, including optimal power flow, transient stability, economic dispatch, and so on. The PSO technique was utilised to tackle the frequency control problem in a two-area system. The two area systems are electrical networks that are linked by generators, transmission lines, and load buses. The purpose of frequency control is to keep the two area systems in frequency balance. The PSO algorithm can be used to optimize the control parameters of the two area systems in order to maintain optimal frequency and power balance. This effort was done to regulate the frequency of two area systems using PSO. It goes over the principles of the PSO algorithm, the structure of the two-area system, and the problem formulation. The study then presents the optimization process's outcomes and discusses the performance of two area systems' frequency regulation using PSO.

1.1. Structure of Two Area System

A two-area system is a network of interconnected generators, transmission lines, and load buses. The two-area system is a distributed system made up of two areas that are linked together. Each region has its own generators, transmission lines, and loads. The transmission lines connect the generators, while the transmission lines connect the loads. The transmission lines are linked, allowing power to be transported between the two zones.

The two-area approach is designed to maintain the best frequency balance possible. This is accomplished by modulating the power output of the generators in each location. The governor, excitation system, and automatic voltage regulator are among the components of the two-area system. These components work together to keep the frequency balance optimal.

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1.2. Load Frequency Control

Power systems are used to generate electricity from renewable or natural sources. Load frequency control (LFC) is critical in power systems for delivering reliable and improved electric power to consumers. However, electric power consumers vary the loads at random and regularly. Changes in load cause generation to be adjusted so that there is no power imbalance, whereas managing power generation is a difficulty. A control system is required to mitigate the impacts of erratic load variations and to keep voltage and frequency within pre-specified limits. Voltage is related to reactive power, but frequency is related to real power balance. Load frequency control (LFC) refers to the control of real power and frequency. If the load in a system changes, the frequency and bus voltages will change as well. LFC, as the name implies, modulates the power flow between different locations while maintaining a constant frequency. LFC is a loop that regulates output in the megawatt range and generator frequency. This is made up of two loops: primary and secondary. The frequency control challenges of interconnected areas are more serious than those of single area systems.

Reasons to hold frequency constant are:

1. The majority of ac motors operate at speeds that are directly proportional to frequency.

If the typical frequency is 50 Hertz and the turbine runs at rates comparable to 2.5 Hertz, the turbine blades are likely to be damaged.

2. Synchronous motors power the electrically operated clocks. The accuracy of these clocks is determined by the frequency and an integral of the frequency error.

Power systems are now linked to surrounding areas. However, integration of electricity networks results in a significant increase in system order. Tie-lines allow this connection to be created.

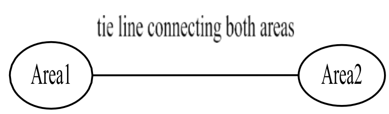

Figure Error! No text of specified style in document.**.1 Figure showing two areas connected by tie-line**

Tie-lines allow electric electricity to travel across regions. The introduction of tie-line power results in the occurrence of a mistake known as tie-line power exchange error. When the load in a location changes, that area will receive energy from other areas via tie-lines. The power flow through various tie lines is planned or set, for example, area i may give a certain quantity of electricity to area j while withdrawing another predetermined amount from kth area. As a result, LFC must additionally control the tie-line power exchange fault. It is claimed that local area information can be gleaned from tie-line power variations. For a two-area system, the tie-line power is measured and the resulting tie-line power is fed back into both areas. Interconnection of power networks also leads to a significant rise in system order. As a result, model and parameter approximations cannot be avoided when modelling such complex high-order power systems.

Hence LFC has two main objectives:

1. To keep the frequency constant against any load change.
2. Flow of power in the tie-line must be maintained to its desirable value in each area.

The control goal is now to regulate the frequency of each area while also regulating the tie line power in accordance with interarea power contracts. In the case of frequency control or bringing a frequency deviation back to the intended level, turbines are controlled, which turn the generators. The proportional plus integral controller is commonly employed for this purpose in order to achieve zero steady-state error in tie line power flow.

1.3. 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 1.2.

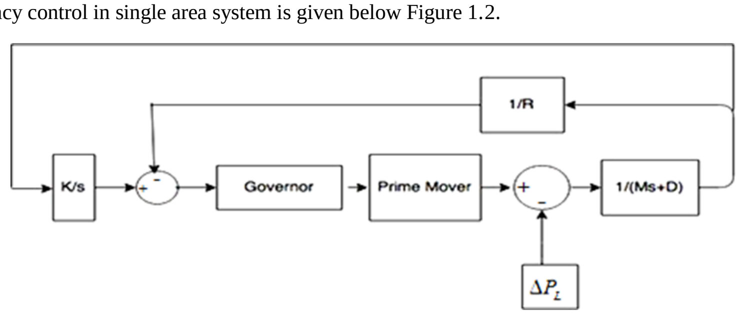

Figure Error! No text of specified style in document.**.2 Load frequency control in single area system**

1.4. Load Frequency Control in Two-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 i^{th} area

ΔP_{12}=changed in tie-line power between area 1 and area 2

b_i = frequency bias constant of i^{th} area

Δf_i= frequency deviation of i^{th} area

Two-area systems are the connecting of two areas via tie-lines. The picture below is a generalised block diagram of a two-area network as shown in Figure 1.3.

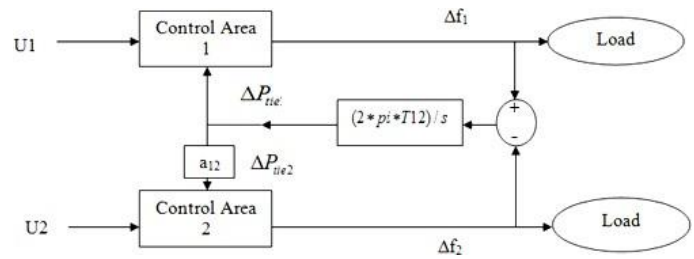

Figure Error! No text of specified style in document.**.3 Block diagram of generalized two area system**

The generators in a two-area system are considered 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,

ΔP_{tie}= tie-line power exchange between area 1 and area 2

T_{ij}= tie-line synchronization torque co-efficient

This equation can be shown in a model as shown below Figure 1.4.

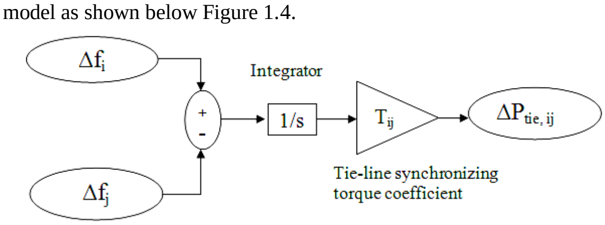

Figure Error! No text of specified style in document.**.4 two area tie-line model**

1.5. Controllers

The fundamental control loop can be simplified for a SISO (single-input-single-output) system as in Figure 1.5 Here we are ignoring the disturbances in the system.

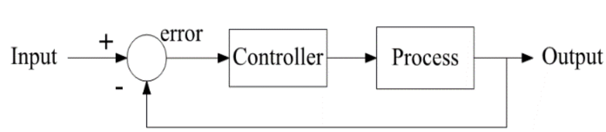

Figure Error! No text of specified style in document.**.5 Basic control loop**

The controller might have several structures. However, the Proportional-Integral-Derivative (PID) type controller is the most widely used. In fact, PID controllers account for more than 95% of all industrial controllers.

The transfer function of the controller is given by:

$$C(s) = K_p\left(1 + \tau_d s + \frac{1}{\tau_i s}\right)$$

Eqn. **Error! No text of specified style in document.**.3

Where K_p=Proportional gain

τ_d=Derivative time, and

τ_i=Integral time

The impacts of the individual components-proportional, derivative, and integral-on the closed loop response of this system are explained in this section.

The temporal response of a proportional controller improves (i.e. the time constant reduces) and there is an offset between the output response and the desired response. This offset can be decreased by raising the proportional gain; however, higher order systems may experience increased oscillations as a result.

When only the integral action of the controller is examined, the order of the closed loop system grows by one. If the process has higher order dynamics, this increase in order may lead the closed loop system to become unstable. The main benefit of this integral control action is that it decreases steady-state error due to step input to zero. However, the system reaction is generally oscillatory, slow, and occasionally unstable.

PI has the dual benefit of quick response owing to P-action and zero steady-state error due to I-action. The steady-state error can be reduced to zero by utilizing a P-I controller, while the transient responsiveness can be improved.

The P-D controller appears to be ineffective since it cannot lower the steady-state error to zero. However, for higher order processes, the P-D controller can be used to improve the stability of the closed loop system.

A well-chosen combination of proportional, integral, and derivative actions can offer all of the required results: quick reaction, zero steady-state error, and low offset. This order is low, however it is globally applicable because it may be applied in any system. PID controllers have also been proved to be robust, which is why they are widely used in industrial processes.

The parameters are adjusted using optimization and an objective function that is a function of error and time, and the function is the integral of time-multiplied absolute error criterion (ITAE).

Another objective function that is a function of error and time is known as the integral of the square of the error criteria (ISE), however this performance indicator is not used because it is computationally difficult and less sensitive than ITAE. Whereas ITAE has the advantages of causing fewer oscillations and lesser overshoots, maintaining robustness, and being the most sensitive (i.e. best selectivity), this makes the ITAE index the preferred criterion for control system design. The emphasis is on lowering the ITAE criterion.

ITAE is made up of both locations' tie line power and frequency variation. The primary function is

$$j = \int_0^{\infty} t\left(|\Delta f_1| + |\Delta f_2| + |\Delta p_{tie}|\right) dt$$

Eqn. **Error! No text of specified style in document.**.4

Where, Δf_1 and Δf_2 are frequency deviations;

$\Delta P_{tie}$is the change in tie line power

Because integrating to infinity is impractical, a large enough value of T should be chosen to ensure that error is insignificant. T=10 seconds is used here.

1.6. 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 problems, it requires extremely little processing 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. Particle Swarm Optimisation (PSO) is an optimization technique based on the flocking behaviour of birds. It is a population-based optimization method inspired by flock behaviour of birds. The

PSO method is based on the idea of particles in a search space representing potential solutions. The particles move around the search space, altering their positions based on their current fitness and the best position discovered by their neighbours. The particles can communicate with one another, conveying information about their current location and the optimal place discovered.

There are various advantages to using the PSO algorithm over other optimization strategies. It is simple to use and can tackle both continuous and discrete optimization problems. It's also computationally efficient and can handle large-scale challenges. The PSO algorithm has been employed in a variety of applications, including optimal power flow, transient stability, and economic dispatch.

2. Research Methodology

Proposed Methodology of Frequency and Power Control of a Two-Area System Using Particle Swarm Optimization (PSO). Particle Swarm Optimisation (PSO) is a stochastic search approach that has been used for optimization in a variety of domains. This work employed PSO to control the frequency of a two-area system.

Step 1: The goal of the study is to minimize the total of the absolute value of the frequency deviations in two locations by managing the power exchanged between them. The following equations are part of the problem formulation:

1. Total Power Balance in the two areas: P1 + P2 = P1_ref + P2_ref
2. Frequency Deviations in two areas: f1_dev = f1 – f1_ref
   f2_dev = f2 – f2_ref
3. Objective Function: minimize f(x) = |f1_dev| + |f2_dev|

Step 2: The PSO algorithm's parameters must be initialized. The parameters include the population size, inertia weight, acceleration constants (c_1 and c_2), and upper and lower variable limits.

Step 3: The optimization technique begins with the generation of an initial population of randomly selected particles.

Step 4: The objective function is used to assess the fitness of the particles.

Step 5: The particles' velocity and position are modified using the PSO algorithm.

Step 6: The particles are ranked by their fitness scores, and the best particle is selected.

Step 7: The power exchange between the two locations is then changed based on the position of the best particle.

Step 8: The particles' fitness is re-evaluated, and the cycle is continued until the optimization target is met.

Step 9: Finally, the best answer is found.

Step 10: Analyse and compare the results to the reference data.

Step 11: Finally, the controller's performance is reviewed.

Particle Swarm Optimisation (PSO) is a strong optimization technique that can control the frequency of two-area systems. In this work, we will go over the step-by-step approach of utilizing PSO to control the frequency of two-area systems.

2.1. Single Area System

It is an electrical region that is separate from the rest of the power system network and has one or more generating units that distribute electricity in the same area. In this specific area, it is the responsibility of the single generating unit to maintain the usual frequency in the event of a system disturbance. These single-area power systems serve as the foundation for bigger multi-area power systems. The properties of a single area network are quite simple and straightforward. In the next sections, we will describe two-area networks.

2.2. Two-Area Systems

In reality, the power system is composed of many single areas that are linked together to form a bigger two-area system. They are linked to one another by tie-lines. Thus, in a two-area system, every fluctuation or disturbance in the load induces a change in frequency and a change in power exchange in the tie-lines. The governor action of the generators must correct this mismatch in power and frequency. This section will go over two area systems with disturbance. Figure 2.1depicts a general representation of a two-area system.

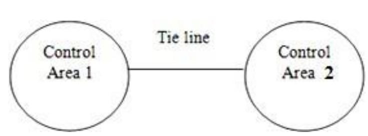

Figure 2.2 Two area system

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

$$ACEi = Pi + bi\Delta fi \quad \text{Eqn.2.1}$$

Where,

b_i = biasing factor

Δf_i = change in frequency of area1

Two areas are dependent on each other in a two-area system. As a result, the ACE for a two-area system can be defined as follows.

ACE for area 1 is given by,

$$ACE_1(s) = P_1(s) + b_1\Delta f_1(s) \qquad \text{Eqn.2.2}$$

ACE for area 2 is given by,

$$ACE_2(s) = P_2(s) + b_2\Delta f_2(s) \qquad \text{Eqn.2.3}$$

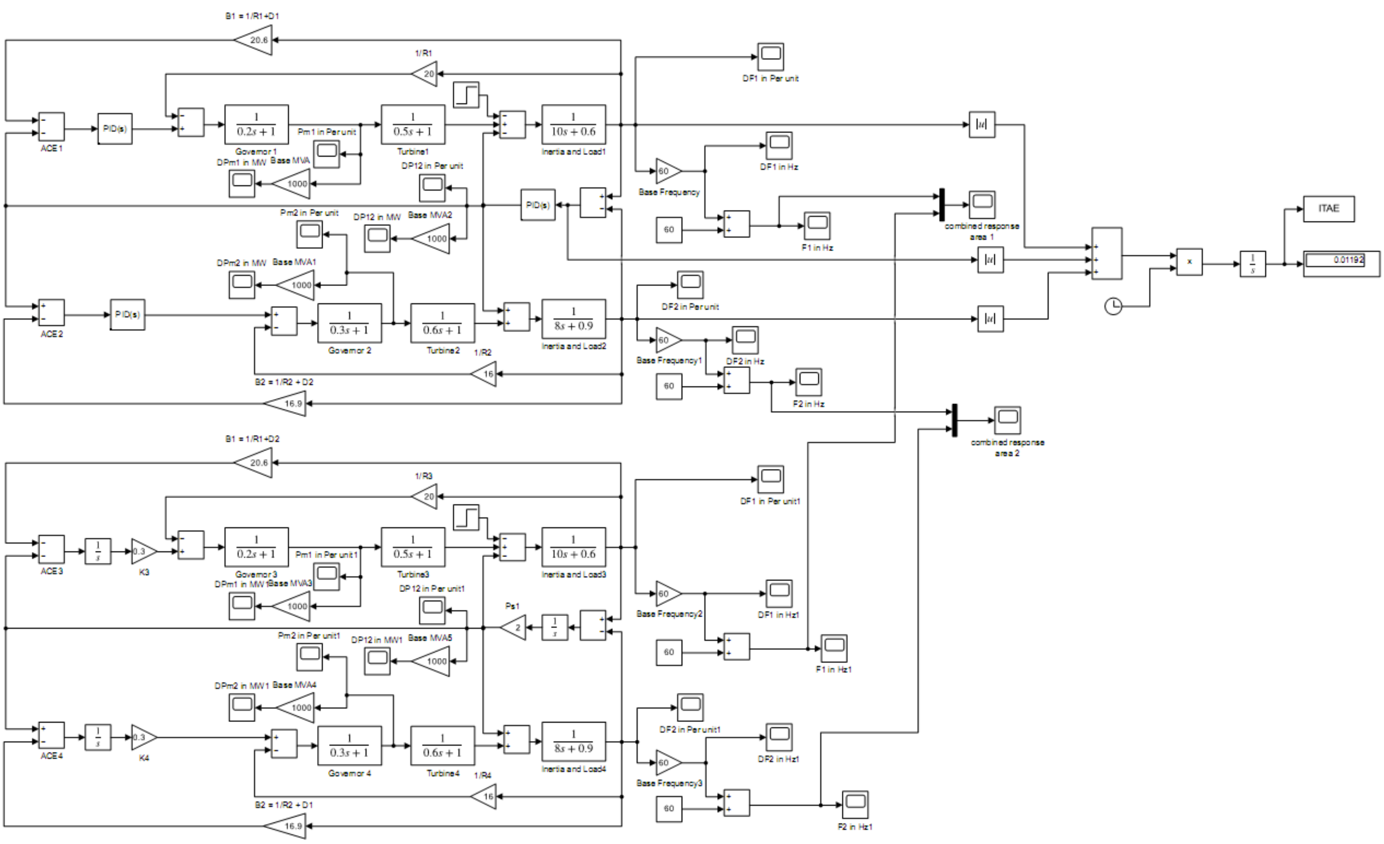

Figure 2.3 PSO Based Automatic Generation Control of two Area Power System

3. Result and Discussion

In this section, investigate the load frequency regulation on single and two-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 to two-area systems.

3.1. Load Frequency Control Using PID Controller

PID controller in two area system

The previous section examined the performance of a single area system. It was determined that the governor is required for frequency stabilization. The Figure 2.3 below depicts the influence of PID controllers in a two-area system.

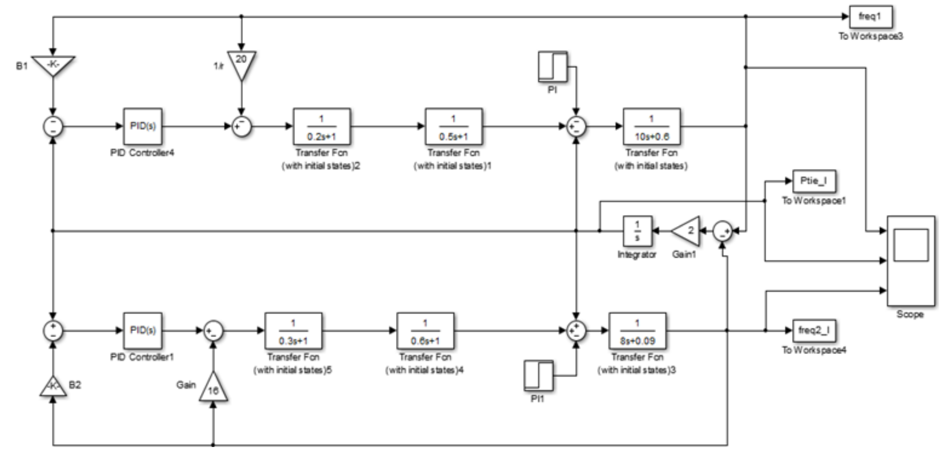

Figure 2.3 PID controller in two area system

Response of the two-area thermal system with I, PI and PID controllers is shown in the Figure 2.4 to Figure 2.8.

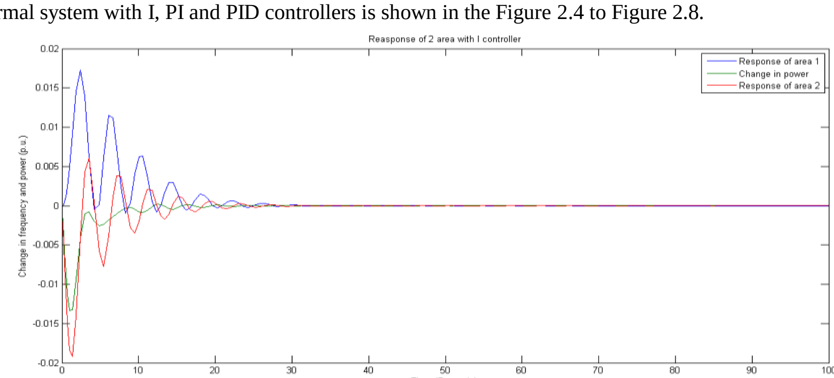

Figure 2.4 Response of two area system with I controller

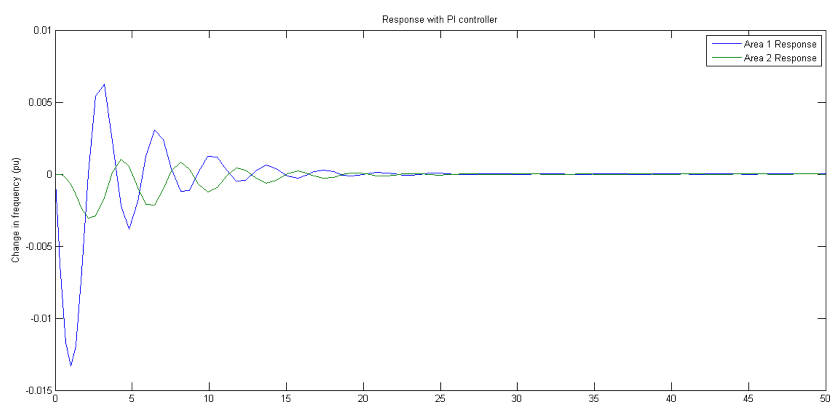

Figure 2.5 Response of two area system with PI controller

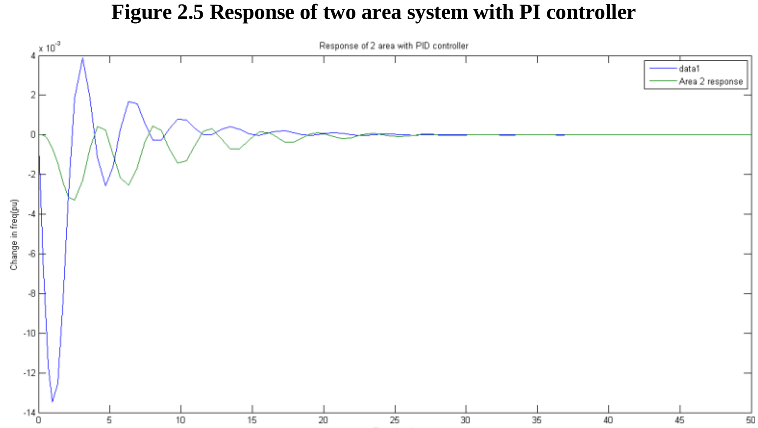

Figure 2.6 Tie-line power in two area system with PI controller

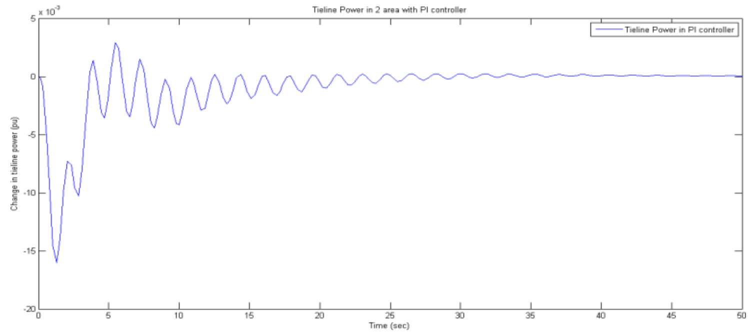

Figure 2.7 Response of two area system with PID controller

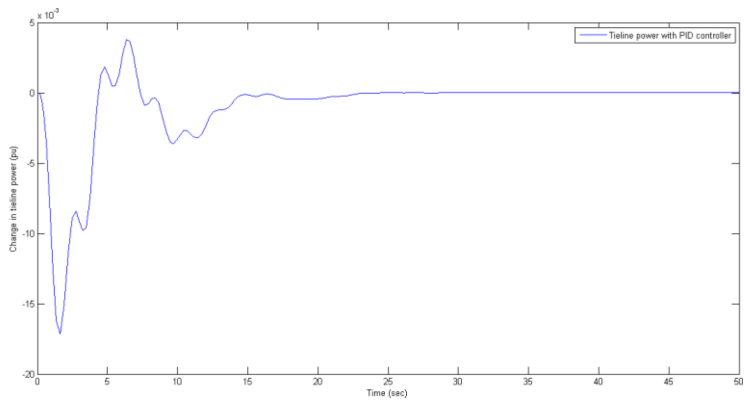

Figure 2.8 Tie-line power with PID controller

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

Table3.1 Area-wise response of two area system

Controller	Settling time (in seconds)		Overshoot (in p.u.)		Undershoot (in p.u.)		Tieline power (in p.u.)
	Area1	Area 2	Area 1	Area 2	Area1	Area 2	On steady state
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

3.2. LFC Using Particle Swarm Optimization

In MATLAB/SIMULINK, a two-area scheme is used. It is depicted in the diagram below Figure 3.1. 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 3.2 and response of LFC using PSO is shown in Table 3.2 for single and two area system.

Table 3.2 Response of two area system with PSO

Settling time (in seconds)		Overshoot (in p.u.)		Undershoot (in p.u.)		Tieline power (in p.u.)
Area1	Area 2	Area 1	Area 2	Area1	Area 2	On steady state
13	14	0.01	0.008	-0.015	-0.015	12

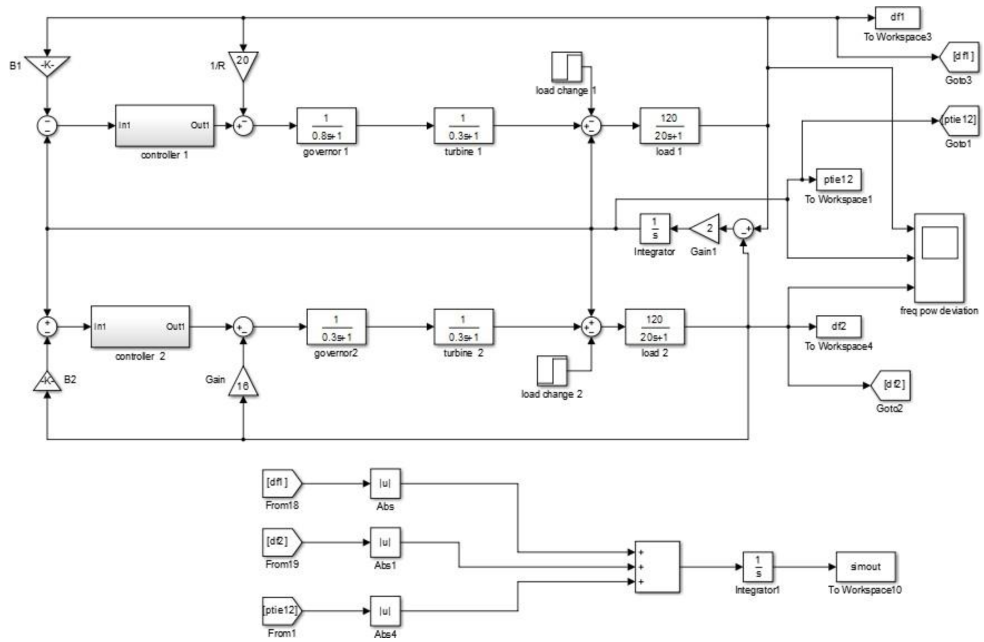

Figure 3.1 Block diagram of LFC two area system with PSO

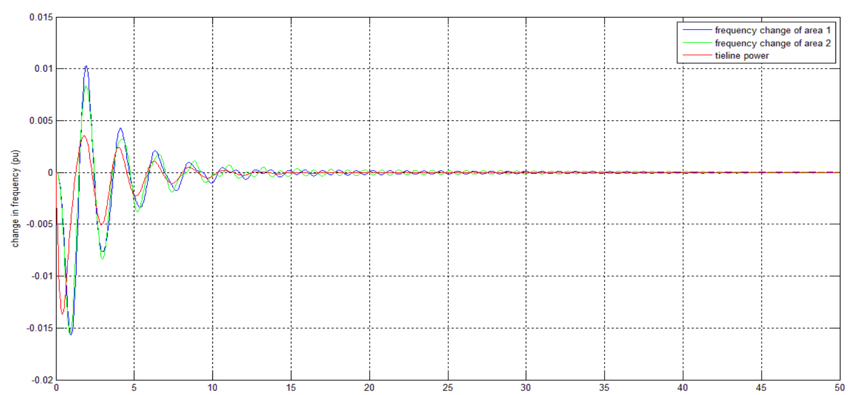

Figure 3.2 Response of two area system with PSO

4. Conclusions and Future Scope

4.1. Conclusions

This research contributes to the Load Frequency regulation in a Two-Area Power Control System and the regulation of load frequency using conventional and intelligent controllers. PID controllers and intelligent controllers PSO are used in the same way. These controllers were used to manage the load frequency with disturbance in region 1 and region 2. Thermal and hydroelectric power plants were employed. With varying I, PI, and PID values, the first PID controller was used.

The result of LFC in terms of settling time from controller PID for Area 1 is 25 second, Overshoot value 0.004 per unit and undershoot 0.013 pe unit and Tieline power 25 whereas the settling time 13 second, Overshoot 0.01 per unit and undershoot -0.015 per unit from using PSO optimization. Similarly getting the response of LFC for Area 2 from PID is 25 second, Overshoot 0.001 per unit and undershoot 0.002 per unit whereas 14 second, Overshoot 0.008 per unit and undershoot -0.015 per unit from PSO optimization. The response from the AGC controller for area 1 also getting the settling time 5.01 second, overshoot time 0.003 per unit and undershoot 0 per unit whereas the response for area 2 settling time 5 second, overshoot time 0 per unit and undershoot 0 per unit after using PSO optimization. Also get the ITAE response 0.01192 after 100 iteration.

The results improved when a PID controller was utilised as a controller in a two-area system. The Particle Swarm Optimisation method was used to optimize the parameters of the PID controller. When the parameters were optimized, the system performed best. PSO optimization was more effective than the PID controller for the both system single is as well as two area system.

In this work, PSO is used to modify the parameters of a proportional-plus-integral controller. A two-area system is utilised to demonstrate the method. The integral of time multiplied by the absolute error was the objective function. Different plots of frequency deviation were created by varying the load demand of sites. The impacts of parameter modification on system response were also plotted and monitored.

4.2. Future Scope

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

1. The created Fuzzy logic controller can be employed in increasingly complicated systems to achieve the best performance.
2. PSO can be combined with a fuzzy controller to improve 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 the case of fluctuating load in power systems.

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