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Review on Load Frequency Control using PSO of Multi Area System

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ABSTRACT

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. Traditional PID controllers and Particle Swarm Optimization-based controllers-based paper result used in this review paper

Keywords:Key word: 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.

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.

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4. To maintain the shortest possible settling time for frequency variations.

1.1. Load Frequency Control in Multi-Area System

Load frequency regulation is an essential component of power systems. It is necessary to learn the essential components of Power Systems in order to fully comprehend it. This section contains information on various Power System components. This chapter explains it using a block diagram of each part and the equations that go with it.

Power Systems: Overview

The goal of electrical power systems is to convert accessible natural forms of energy into electrical energy using electric generators and then deliver it to end users located far from the generating unit. The generating unit could be a thermal, hydro, or nuclear facility, and the energy produced is delivered to consumers via transmission lines. An electrical power system is an interconnected system with a complicated structure that is separated into several various subsystems known as the Generation, Transmission, and Distribution subsystems. These mechanisms are detailed in detail in the paragraphs that follow. It is critical that this project's research include an understanding of the following areas.

Generation

It is one of the most critical components in power systems. It is made up of alternating current generators, often known as Synchronous Generators or Alternators. Synchronous generators are made up of synchronous rotate fields within them. One field is generated in the rotor, which is driven by DC incoming current and rotates at a speed known as the synchronous speed, while the other field is generated in the generator's 3-phase AC windings in the stator. The direct current delivered to the rotor winding excitation systems. A normal generator's excitation system is used to maintain generating voltage and to manage the flow of reactive power in the generator.

The prime movers provided mechanical power to the thermal station generators, while the steam turbines derived their energy from the combustion of fossil fuels such as coal, natural gas, and nuclear fuel. In India, steam turbines operate at extremely high speeds of 3000 and 1500 rpm. They are connected to cylindrical rotor generators that have two poles for 3000 rpm operations and four poles for 1500 rpm activities. When opposed to steam turbines, hydraulic turbines operate at a slower speed. Their generators are the prominent rotor type with an excessive number of poles.

In the existing power system network, numerous generators work in parallel to produce power to the power grid in order to meet end-user load demand. They are all linked to a central place known as the Bus. According to today's environmental conservation theory, several other valuable alternate energy sources for power generation are explored, including solar power, wind power, geothermal power, tidal power, and biomass.

Transmission and Sub Transmission

This is the part of the power system that connects the generation and distribution sides for the following functions:

1. To supply electricity generated by generators to end loads attached to the distribution side of power systems.
2. For interconnection with neighboring power utilities for economic load dispatch and inter-area power transfer during power outages.

Industrial users with high power demands may be supplied directly by the existing transmission power infrastructure. The Sub-transmission power network is the section of the transmission power system that connects high voltage substations to distribution substations. Capacitor and reactor banks were typically installed within substations to maintain the requisite voltage in the transmission line.

Distribution

The distribution system is also a component of a power system that connects the various distribution substations to the network's end users. The secondary distributions, known as substation lines supply, reduce the voltage level for use by commercial and residential end users of electric power. A transformer lowers down the incoming voltage to the required voltage level to meet the electricity requirements of any average home.

Loads

The loads in power systems are classified as follows: industrial load, commercial load, and residential load. The transmission system supplies the very big industrial loads directly. The large industrial loads are supplied with power directly from the sub-transmission system, while the minor industrial loads are supplied with power via transformers from the primary distribution network. These industrial loads are predominantly composite loads, with induction motors accounting for a major share of them. The commercial and residential loads are mostly made up of lighting, heating loads, and cooling loads. These loads are primarily frequency independent and utilize very little reactive power.

1.2. WorkingSystemDescription

The real power system network is made up of numerous components such as generators, transmission lines, loads, controllers, and protective devices. The dynamics of a system are determined by its constituent constituents. So, if we wish to examine any system, we must first understand the numerous pieces that comprise it. This part introduces the elements of the power system model to be utilized in the thesis for single-area and multi-area systems, as well as their related transfer function models. The first is the generator model.

Generatormodel

The generator set unit of this model converts the mechanical power of the turbine to electrical power. The goal of our LFC research is to determine the output speed of the rotor because the frequency in power systems is dependent on it. In LFC, rotor speed is used instead of energy transformation. Because it is difficult to store such large amounts of electrical energy created by the generator, it is critical to maintain a real-time balance between the power generated by the generator and the end load demand.

If the load changes at any point, the mechanical power output of the turbine does not match the electrical power generated in the generator. The difference between turbine mechanical power (ΔPm) and generated electrical power (ΔPel) is integrated with deviations in rotor speed (Δωrr), which is given in terms of frequency system changes (Δf), and multiplied by two. Figure 1.1 depicts the relationships in terms of ΔPm and Δ f, where M denotes the generator's inertia constant.

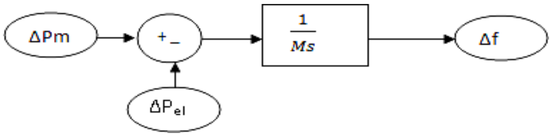

Figure Error! No text of specified style in document.**.1 Generator's block diagram**

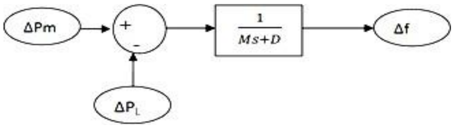

Figure Error! No text of specified style in document.**.2 Load's block diagram**

Load model

The loads in our study are categorized as:

1. Resistive loads (ΔPL), they remain unchanged when the rotor speed changes,
2. Motor loads which vary with the load speed.

If the mechanical power input to the generator remains constant, the motor loads balance the load change by altering the rotor speed to a value other than the fixed value, as indicated in the figure below.

where D is the load damping constant.

Primemovermodel

In the case of a steam turbine, the model of the prime mover keeps track of the input steam supply to the generator, and in the case of a hydro-generator turbine, it keeps track of the boiler's control system.

The model of the prime mover system is shown below

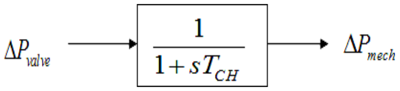

Figure Error! No text of specified style in document.**.3 Prime mover's model**

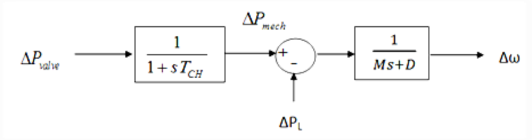

Figure Error! No text of specified style in document.**.4 Prime mover-load model**

Figure 1.4 give the relation between the turbine supply to the power output of the turbine. Where,

TCH = "charging time" time constant.

ΔPvalve = per unit change in valve position from nominal.

The Governor models

The governor is the component of the system that senses frequency deviations caused by fluctuations in load and regulates them by adjusting the inputs to the turbines. Figure 1.5 depicts the controlling unit's block diagram.

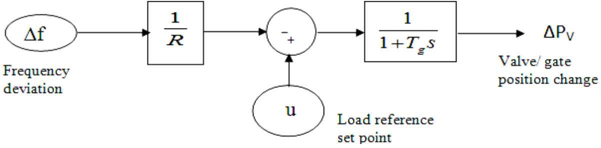

Figure Error! No text of specified style in document.**.5 the governor model**

here, R is the speed regulation characteristic and Tg is the time constant of the governor.

If there is a change in load without a load reference, a portion of the change is balanced by adjusting the valve position, and the remainder is in the form of frequency change. The primary goal of LFC research is to control frequency variations caused by varying active power load.

Turbines

A turbine's function is to transform any form of energy accessible to it into mechanical energy. Inside a generator, mechanical energy generates electricity. The primary focus of this LFC research is on three types of turbines: reheat turbines, non-reheat turbines, and hydraulic turbines.

1) **Reheat Turbines**

Because of the different periods of low and high pressure, they are of second order in nature. Their transfer function is denoted as,

$$G_R = \frac{F_{hp}T_{rh}s + 1}{(T_{ch}s + 1)\,(T_{rh}s + 1)}$$

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

Where

Trh= low pressure turbine reheat time

Tch = switching valve time

2) Non-reheat Turbines

Because there are no extra stages, such as reheat turbines, they are single order in nature. Their transfer model function can be represented as follows:

$$G_{NR} = \frac{1}{(T_{ch}s + 1)}$$

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

Tch = switching valve time

3) Hydraulic Turbines

They are turbines of the non-minimum type. In the hydraulic turbine transfer function model, water inertia introduces a zero on the right side of the jw axis. The hydraulic turbine's transfer function is shown below.

$$G_H(s) = \frac{-T_w s + 1}{0.5T_w s + 1}$$

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

Where

Tw = time constant

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.

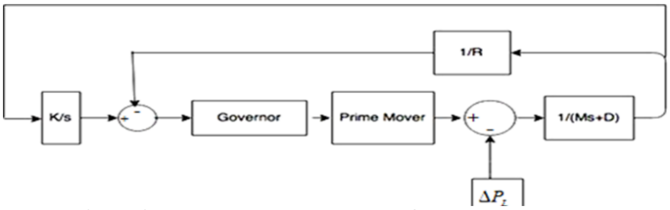

Figure Error! No text of specified style in document.**.6 Load frequency control in single area system**

1.4. 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.**.4

Here,

ACE=Area Control Error of ith area

$\Delta P12$=changed in tie-line power between area 1 and area 2

bi = frequency bias constant of ith area

Δfi= 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 1.7.

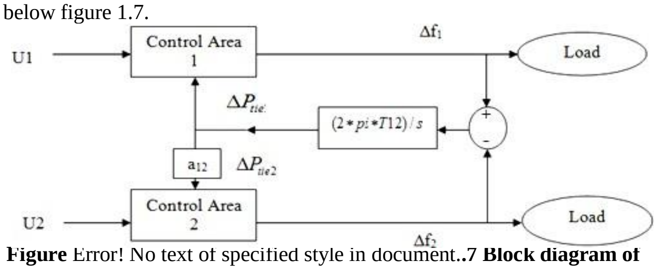

Figure Error! No text of specified style in document.**.7 Block diagram of generalized two area system**

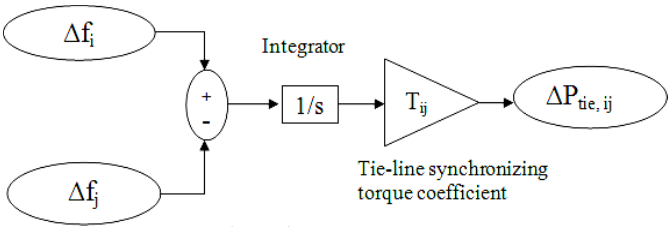

Figure Error! No text of specified style in document.**.8 twoareatie-line model**

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.**.5

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 figure 1.8.

1.5. 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. LITERATURE REVIEW

DolaGobindaPadhan, and Somanath Majhi 2013, explained in order to develop a PID load frequency controller for power systems, a new control structure with a tuning mechanism is proposed. The controller is initially created for a single area power system before being expanded to a multi-area situation. By applying the Laurent series to increase the controller transfer function, the controller parameters are obtained. A relay-based identification technique is used to gauge the dynamics of the power system. Regarding uncertainties in the plant characteristics, robustness tests on stability and performance are offered. For any bounded uncertainties and system oscillations, the suggested scheme guarantees that the entire system is asymptotically stable. The suggested strategy greatly increases the load disturbance rejection performance, according to simulation findings, even when plant parameter uncertainties are present [1].

H. K. Shaker et al. 2020, studded the linked hydro, wind, and thermal power systems' load frequency control (LFC). A variety of tests were conducted, recorded, and analysed by various types of controllers. PID, fractional order PID, fuzzy PID, and fuzzy fractional order PID controllers are examples of these types. Particle swarm optimisation (PSO) was used to optimise various controller gains using the integral time absolute error (ITAE) objective function. Performance of the system under PID, FOPID, FPID, and FFOPID controllers is compared. This comparison was done in order to determine the best controller to use with the suggested setup. The primary objective of LFC is to restore the frequency and power transfer over the tie line to their initial values just prior to the disruption or to close the gap between the offset in power transfer through the tie line and the offset in frequency. The simulation results in this work were attained when a 1% step load disturbance was applied to the load in the conventional second region (thermal area). The data and resulting curves are all displayed using the MATLAB SIMULINK programme [2].

M. J. Chandrashekar and R. Jayapal 2013, described Two thermal power generating units are placed in each of the two control areas. Dynamic analysis is performed for a system having an HVDC connection running parallel to an AC tie line. The use of frequency stabilisation in connected power systems is a benefit of HVDC links. Open transmission access and appraisal of more socially responsible businesses are what cause the Automatic Generation Control (AGC) system to suffer. As a result, the traditional two-area approach has been modified to consider the impact of bilateral contracts on dynamics. The dynamic response of the two-area hydro thermal system is deteriorated and sluggish when compared to the HVDC link ac tie line. The impacts of Integral, PI, PID, and fuzzy controllers with and without HVDC on a connected two-area power system operating in a deregulated environment are covered in this study. Frequency deviation is modelled with various controllers using Matlab-Simulink. Plots of the responses of tie-line power deviation and frequency deviation are made for several controllers with the best gain values, and the results are compared to the performance of the suggested fuzzy logic controller [3].

M. S. Redoy and Ruma 2022, designed a Particle Swarm Optimisation (PSO) optimisation technique combined with a conventional Proportional-Integral-Derivative (PID) controller that provides the best Load Frequency Control (LFC) in the situation of changing load. Better solutions in terms of rising time, settling time, minimum overshoot, and tie-line error are offered by the suggested PID-PSO controller. In the suggested simulation model, a tie-line connection links two power zones with multiple sources of generation. The PSO method is used to fine-tune the PID controller's parameters for optimum output. Utilising MATLAB software and SIMULINK, the system was constructed and simulated. In terms of frequency deviation, tie line error, and settling time, the results are reported [4].

N. Kumari and A. N. Jha 2014, explained an optimal control system technique known as the Linear Quadratic Regulator (LQR) along with proportional integral (PI) controller is designed for the frequency response enhancement of the system in this paper. The mathematical modelling of two area networks with connected thermal power systems has been done on the state space. Along with other state variables, the PI controller gains are used as the system for automated generation control's (AGC) optimal state-feedback gains. The method has been thought of with the reheat turbine for thermal zones. For a system with properly designed automatic generation control, the variation in frequency should be minimal as the system's load varies. The Linear Quadratic Regulator (LQR), an optimum controller, is modified using the potent computationally intelligent Particle Swarm Optimisation (PSO) method to improve the frequency response to load variations. The block diagram of the two-area interconnected thermal power system is designed first in the current study. The state equations for the power system are then determined for the various block diagram states in order to create the state space model. Utilising MATLAB/SIMULINK, the proposed PSO based LQR technique for autonomous load frequency regulation of a two region thermal power system was created [5].

N. Modi et al. 2013, studied of to find the best proportional-integral-derivative (PID) controller parameters for load frequency management in a single area power system, genetic algorithms (GA) and particle swarm optimisation (PSO) were used. The performance of the controller is enhanced for the step input in load frequency management when compared to the proposed PSO and the conventional Proportional-Integral (PI) technique. In order to find the best proportional integral-derivative (PID) controller parameter for load frequency management in a single area power system, this research compares the performance of the Genetic Algorithm (GA) and the Particle Swarm Optimisation (PSO) technique. Software called MATLAB-Simulink is utilised for this application [6].

Nour E.L et al. 2015, described in an integrated multi-area power system, tie-line power flow interchange and area frequency both alter in the event of any slight, rapid load change in any of the areas. The main objectives of load frequency control (LFC) are to manage the change in the tie-line power flow between control zones as well as to maintain the frequency and intended power output in the interconnected power system at the scheduled values. This paper's main goal is to provide a PID controller-based load frequency control application based on fuzzy logic controllers (FLC) in a multi-area linked power system. To find the best values for the PID controller parameters, fuzzy logic is used. The simulation makes use of a three-area, nine-unit model system, and the transient reactions to step load perturbations in areas 1, 2, and 3 are displayed. The major goal is to eliminate any frequency and tie-line power fluctuation in the system. The efficiency of the suggested method is validated against the traditional Ziegler-Nichols methodology (Z-N) and the heuristic Particle Swarm Optimisation method (PSO) [7].

P. C. Nayak et al. 2018, described the concept of a multi-PID-based load frequency control technique for a multi-source, three-area power system. One thermal unit with a reheat type turbine is present in each region, along with a Generation Rate Constraint (GRC). For each of the three control zones, a fuzzy based PID controller is used. The suggested multi-PID controller's performance is assessed using the objective function Integral of time multiplied with absolute error (ITAE), and its performance is then contrasted using PSO and SOS optimisation strategies. According to the investigation, utilising a fuzzy PID controller with SOS improves the proposed system's robustness significantly when compared to using a POS [8].

P. S. Hosseinian et al. 2021, proposed mismatch between production and consumption causes the power system's frequency to deviate, which has an adverse effect on the system's operation, dependability, and efficiency. Utilising secondary/load frequency controllers, the power imbalance can be corrected over a period of several minutes. The frequency has been controlled using the Linear Quadratic Gaussian (LQG) control. However, the LQG method's parameters are often chosen through trial and error procedures. This makes choosing a large power system difficult and makes it impossible to ensure a positive outcome. The Particle Swarm Optimization (PSO) approach is used to optimize the selection of LQG parameters for a multi-area system in this paper's optimal load frequency control (LFC) method. Simulations are used to confirm the performance of the proposed LQG+PSO approach on a three-area test bench. It is shown that the proposed LQG+PSO method regulates frequencies more effectively than the traditional LQG method [9].

R. Nageswara.Rao and P.Rama Krishna Reddy 2011, focused with Particle swarm optimisation (PSO) algorithm-based optimal tuning of a PID controller for a load frequency control of a two-area power system. The suggested method has several excellent qualities, such as simple implementation, consistent convergence traits, and very high computing performance efficiency. The major goal is to tune the PID controller using the PSO algorithm in order to provide a stable, reliable, and regulated system. The value incurred is better when compared to more established tuning methods like Ziegler Nichols. The MATLAB-SIMLINK environment is used to model and simulate the interconnected two-area LFC system, and the PID control parameters are optimised using the PSO technique. The results show that applying the PSO technique to tune the PID controller resulted in reduced overshoot, a less sluggish system, and a smaller integral Time absolute error (ITAE). The ideal controller is created using the Particle Swarm Optimisation approach, which discovers the best parameters for the controller [10].

Sukhwinder Singh Dhillona et al. 2015, described research of the multi-area power network using heuristics. To efficiently acquire the optimised benefits of PID controller, heuristic approaches utilising Particle Swarm Intelligence and fuzzy based inferences have been used. Any alteration in the load demand reduces the generator's shaft speed below the predetermined value, and any deviation in system frequency from the target value leads to frequency relays malfunctioning. In order to regulate the frequency deviations, PID (Proportional, Integral and Differential) controllers are used to build a five-area load frequency model in Matlab/Simulink. There has been discussion on the results of connecting a multi-area power grid as a ring link. Simulations demonstrate the superior performance and execution efficiency of the current approach compared to simple fuzzy inferences [14].

V. Van Huynh et al. 2021, designed of the principal frequency control of multi-area interconnected power networks with integrated renewable power generation is compensated for using highly robust observer sliding mode (HROSM)-based load frequency and tie-power regulation. First, a state space model of the power system with external disturbance is created. The system states that are expensive or difficult to measure are then estimated using the state observer. Second, a new single phase sliding surface (SPSS) is used in the design of the sliding mode control (SMC). Additionally, the Lyapunov stability theory based on the linear matrix inequality (LMI) method is used to demonstrate the asymptotic stability of the entire system. The new SPSS assures quick convergence of high transient frequency, tie-power change, and eliminates chattering without sacrificing accuracy without reaching time. Therefore, effective practical application is essential to the supremacy of contemporary, cutting-edge SMC-based frequency controllers. When compared to other contemporary state-of-the-art controllers, the experimental simulation findings on large interconnected power systems demonstrate good performance and high robustness against external disturbances in terms of overshoots and settling time [15].

Vandana Dhawane and Rajankumarbichkar 2020, presented using an integral controller, automatic generation control (AGC) is performed on a power system. Maintaining the quality of the electricity produced in today's power systems has become critically necessary, demonstrating the requirement for a robust system that can handle parameter uncertainty neglecting interruptions. Even though there has been a lot of study done in this field, designing a reliable and efficient system is still one of the most crucial problems that needs to be solved. As a result, an integral controller for a single-area thermal power system without a reheat turbine has been developed in this study. Particle Swarm Optimisation (PSO), based on the Integral of Absolute Error (IAE) and Integral of Square Error (ISE) criterion, yields the best controller gain. Testing the developed controller's resilience against various load circumstances and plant parameter modifications is part of the investigation's second phase. The results are contrasted with those from other control approaches that have been recently published in literature. The simulation's findings support the approach's advantage in terms of better transient responsiveness and robustness to changes in plant parameter [16].

W. Yinsha et al. 2019, explained with the frequency of the electrical system is being affected more and more by the large-scale doubly fed induction generator (DFIG) wind turbines that have been introduced into the system. Studying automatic generation control (AGC) optimal control of multi-area interconnected power systems with DFIG wind turbines is crucial since the demand for frequency regulation in the power system is rising as a result of the penetration of wind power. This study establishes the multi-area frequency regulation equivalent model that is a part of the AGC system with a DFIG wind turbine. When the system load is disturbed by this model, the DFIG wind turbine can actively participate in area frequency control on the AGC system and enhance the effectiveness of area frequency regulation. The proposed PSO-fuzzy algorithm is utilised to optimise the parameters of the fuzzy-PI controller of the AGC because the model also enhanced the complexity of the AGC controller. According to the simulation results, DFIG wind turbines actively participate in AGC and enhance the effectiveness of area frequency control to mitigate load disturbance. The PSO-fuzzy algorithm-optimized controller may decrease area frequency deviation, tie-line power change, stabilization time, and frequency fluctuation amplitude, all of which increase power system stability [17].

X. Guo and X. Liu 2014, presented the application of PSOSMC (particle swarm Optimisation sliding mode control) on load-frequency in multiple-area connected power systems. In comparison to previous schemes, the PSOSM controller not only reduces huge overshoots that happen at the time of a step change in parameters, but also makes establishing the parameters for its control law simple and straightforward. We all know that determining the best controller parameter that defines the sliding surface can be challenging, particularly for big multi-input systems. The switching vector and feedback gains in the control law are both optimized using the PSO algorithm. The suggested methodology considers the nonlinearity of the power system as well, including the generation rate constraints (GRC) problem and the governor's valve limit. A four-area connected power system is used to test it. Simulation results show how successful the suggested control algorithm is [19].

3. RESEARCH METHODOLOGY

The process of managing the frequency and tie-line power exchanges in a multi-area power system is known as load frequency control (LFC). It is a method of keeping the system's generation and load in balance. Load frequency control aims to keep the frequency and tie-line power exchanges at the optimal levels.

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.

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

3.1. 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 inputis 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.

3.2. 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. This allows us to investigate more sophisticated multi-area networks. In the next sections, we will describe numerous single-area networks.

3.3. Multi-Area Systems

In reality, the power system is made up of numerous individual sections that are linked together to form a broader multi-area system. They are linked to one another by tie-lines. Thus, in a multi-area system, a change in load or a disturbance in any region 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.

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. **Error! No text of**

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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. **Error! No text of specified style in document.**.7

ACE for area 2 is given by,

$$ACE_2(s) = P_2(s) + b_2\Delta f_2(s)$$ Eqn. **Error! No text of specified style in document.**.8

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

3.4. 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.

3.5. PIDControllers

PID controllers are the most frequent controllers utilized for numerous control operations. They are used in this part for load frequency management in single and multi-area systems. PID controllers are composed of three controllers: Proportional (P), Integral (I), and Derivative (D). These controllers are addressed further below.

Proportional controller

The P controller in PID controllers provides a proportional controller. The output of this controller is proportional to the input error to the controller. That is why it is known as the proportional controller. The equation below represents the controller's representation.

$$U_c(t) = K_p e(t)$$ Eqn. **Error! No text of specified style in document.**.9

The above illustration is in the time domain. To represent it in the Laplace domain, we use the following notation,

$$U_c(s)=K_p E(s)$$ Eqn. **Error! No text of specified style in document.**.10

$K_pistheproportionalgainofthecontroller$
Fig 3.1 shows the block diagram of P controller in both time and Laplace domains

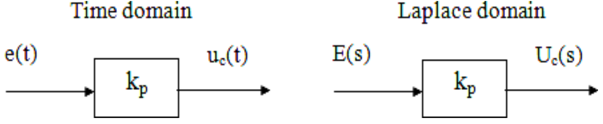

Figure Error! No text of specified style in document.**.1**
Blockdiagramofproportionalcontroller

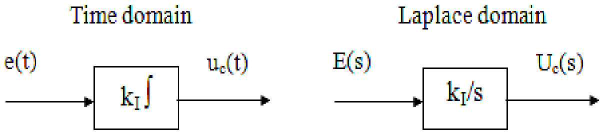

Figure Error! No text of specified style in document.**.2**
BlockdiagramofIcontroller

IntegralController

The, I controller in PID controllers provides an integral controller. The output of this controller is proportional to the integration of the controller's input error. This is why this controller is known as an integrated controller. The equation below represents the controller's representation.

$$U_c(t) = K_i \int e(t)\, dt$$ Eqn. **Error! No text of specified style**

in document..11

The above representation is in the form of time domain. For representing it in the Laplace domain we represent it as given below,

$$U_c(s) = K_i E(s)/s$$

Eqn. **Error! No text of specified style in document.**.12

K_i*istheintegralgainofthecontroller*

Fig 3.2 shows the block diagram of I controller in both time and Laplace domains

DerivativeController

In PID controllers, the D controller provides a derivative controller. The output of this controller is the derivative of the controller's input error. That is why this controller is known as a derivative controller. The equation below represents the controller's representation.

$$\bigcup_c (t) = k_d \frac{de(t)}{dt}$$

Eqn. **Error! No text of specified style in document.**.13

The above representation is in the form of time domain. For representing it in the Laplace domain we represent it as given below,

$$U_c(s)=K_d sE(s)$$

Eqn. **Error! No text of specified style in document.**.14

Kdistheintegralgainofthecontroller

Fig 3.3 shows the block diagram of I controller in both time and Laplace domains

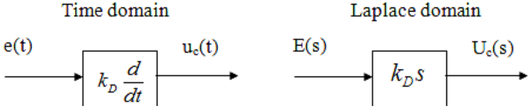

Figure Error! No text of specified style in document.**.3 Blockdiagramof Dcontroller**

When compared to the proportional and integral controllers, this derivative controller must be used with caution. This is due to noise amplification in the system caused by the derivative controller. So, if we use this derivative controller in our system, we should keep this in mind.

3.6. PIDController

configuration. Equation of a normally used PID controller is

$$U_c(s)=\left[k_P+\frac{k_I}{s}+k_D s\right]E(s)$$

Eqn. **Error! No text of specified style in document.**.15

Structure of the PID controller used in the work as given in the Fig 3.4 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.

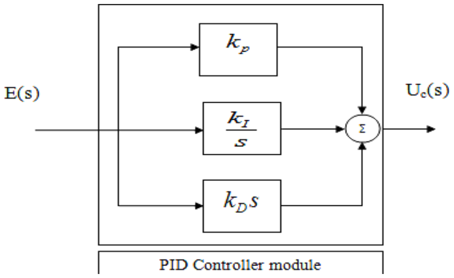

Figure Error! No text of specified style in document.**.4 PID controllerblockdiagram**

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.

3.7. PIDTuning 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:

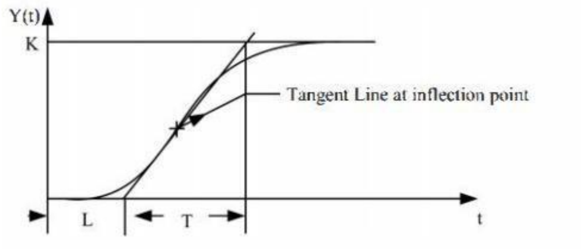

Figure Error! No text of specified style in document.**.5 Ziegler-Nicholsmethod**

Table Error! No text of specified style in document.**.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**

3.8. Load Frequency Control Using PSO Controller

The Particle Swarm Optimization approach is used in this part to investigate load frequency control. To investigate the LFC in a multi-area system, a MATLAB/Simulink model is utilized. In the last part, I used PI and PID controllers to investigate LFC in multi-area systems. Traditional controllers such as I, PI, and PID are widely utilized in LFC situations, but their parameters are extremely difficult to compute in a large multi-area system. We employ many optimization technologies to overcome this problem. The PSO optimization approach will be used in this section. PSO is more effective in controlling model frequency variation and achieving steady state in the shortest amount of time. PSO will be used to modify the PID controller's parameters in order to provide the best solution to the LFC problem.

3.9. 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.

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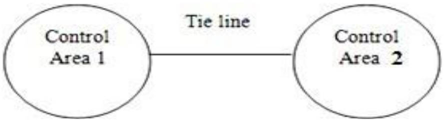

Figure Error! No text of specified style in document.**.6 two area system**

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

$$ACEi = Pi + bi\Delta fi \qquad \text{Eqn. 3.116}$$

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,

$$ACE_1(s) = P_1(s) + b_1\Delta f_1(s) \qquad \text{Eqn. 3.117}$$

ACE for area 2 is given by,

$$ACE_2(s) = P_2(s) + b_2\Delta f_2(s) \qquad \text{Eqn. 3.13}$$

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

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

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 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.

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