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Validation and Simulation of Load Frequency Control for Two Area Connected Hybrid Power Systems

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Abstract: It's a crucial task to keep balance amongst the production and consumption of electricity in interconnected power systems. Load Frequency Control (LFC) is useful in such a circumstance. LFC is essential to making sure the sharing of power and maintaining frequency stability of systems. This paper has evaluated and validated the LFC based three area interconnected power systems. The performance optimization is achieved base on the use of Fuzzy influence system (FIS). In this research, an attempt is made to use a three-area interconnected hydrothermal process PS to examine the dynamic operation of LFC using FIS. The performance is assessed and certified based on loaf-frequency, frequency-time, and power-time parameters. The paper initially studied the influence of variations in load, generator speed, and frequency. The hybrid system with hydro generator and thermal systems are considered.

Key Words: Power System, Load Frequency Control, Fuzzy Logic Control, Optimization methods, Stability, Automatic gain Control (AGC).

1. Introduction

In recent times with the increasing load and demand of power supply lot of research has been carried out to automatic management of power system (PS) performance. Amongst the different approaches the load frequency control (LFC) has now become the essential part of the most PS's.

In recent time with the increasing and dynamic demand interconnected PS are being used in different areas.Recently hybrid PS with integration of solar PV and thermal and hydro grids are in design such as Sambit Dash (2020), Syed Mahboob et al (2022). The optimization methods are frequency being used for performance improvement with LFC systems as greywolf optimization (GWO) Dipayan Guha et al (2015) and PSO byDiem-Vuong Doan et al {2022). Many researchers have worked on fuzzy logic based PS controller [

In this paper an effort is being made to use a three-area interconnected hydrothermal processes PS to study the dynamic functioning of LFC employing FIS. The performance is measured and validated phased on loaf-frequency, frequency-time, and power-time characteristics. Paper has initially evaluated the impact of variation in load, variation in speed of generator, and variation in frequency.

The main goal of this study is to build and validate a load frequency control (LFC)-based power system management methodology. In a power network, the reactive as well as active energy requirements always change in tandem with the upward or downward trend. Hydro-generators (HGs) depending on power input stream input or HG watering intake have to be continuously changed according to load so as to satisfy the present power demand. In the event of an imbalance or synchronisation breakdown, frequencies and machine velocity may vary accidentally. In order to maintain a balance between reactive production along with reactive electricity demand, generators' stimulation must also be continuously regulated. If this isn't done, voltages at various system bridges may exceed permitted limits.

The PS is containing the two types of control mechanisms as illustrated in Figure 1. The primary control is responsible mechanical control works under the normal operation of PS. But in case of excessive over lodging secondary control methods are required. While secondary response to frequency control is a centralised control under the direction of the system operator, primary control usually is a result of local controllers reacting to a frequency variation.This frequency management carried out through governor action is referred to as "primary control". The controls function automatically. The controller responds by increasing its inputs and output as a load increases while speed lowers. Through an assessment of the methods' performance in a single energy system region, this paper suggests a distributed control methodology for multi-area electrical system load frequency management. A reliable stabiliser controller is implemented by utilising multiple modern control algorithms.

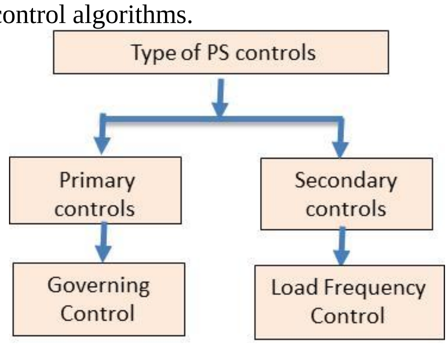

Figure 1 type of PS control methods

2. Applications of load frequency control

The LFC, a crucial component of the electrical grid's operation, ensures the stability and dependability of the electrical system by balancing the supply and consumption of power while maintaining the frequency within preset limits. Some significant applications for load periodicity control are illustrated in Figure 2. Each of these applications is briefly described in this section as motivation of the research.

Keeping the System Stable: The two main task of LFC in PS are

• Frequency Legislation: LFC is used to maintain the overall frequency close to their nominal rate, like 50 Hz or 60 Hz that is necessary for the stable operation of electrical equipment including the electrical network power grads

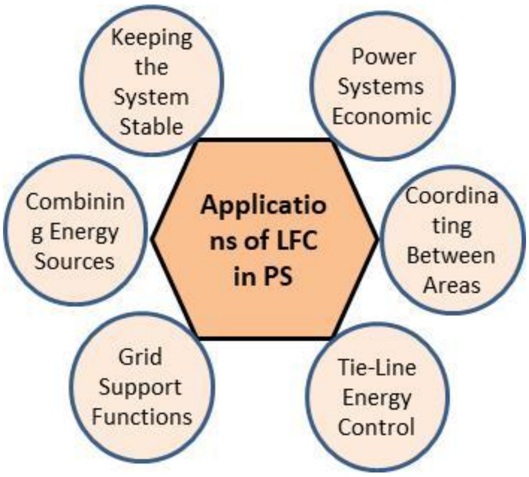

Figure 2 Applications of LFC in PS design

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- Voltage Control: By regulating reactive power, LFC aids in maintaining proper voltages, that are crucial for system reliability and preventing device damages.

Integrating Renewable Energy Sources: the controlled frequency may offer successful combining of energy sources or systems and have following uses.

- Renewable Collaboration: LFC facilitates the integration of fluctuating clean energy sources, such as sunshine and wind, by adjusting the electricity provided by traditional providers to balance the unpredictable and variable nature of renewable power.
- Grid Security alongside Substantial Renewable Penetration was: When LFC networks contain a large percentage of green power, they can swiftly adapt to changes in the availability of power, giving the grid stability.

PS's Economic Operations: the control operation offers

- Optimal Generating Dispatch: LFC helps with the economical dispatch of power plants, ensuring that energy is produced and delivered at the lowest possible cost while maintaining system stability.
- Cutting Operational Expenditures: By efficiently managing the producing sources, LFC reduces operational expenses as well as fuel use.

Networking the Power Systems: by interconnecting LFC offers PS networking capabilities as;

- Coordinating Amongst Areas: LFC ensures that different control regions in connected energy systems operate in concert, maintaining intended energy transfer and consistent frequency between areas.
- Tie-Line Energy Transfer Controlling: By managing the electricity flow through tie-lines linking different control regions, it preserves equitable load distribution and prevents overpowers.

Grid Supporting Functions: One of the services it offers is black start capacity, which is the process of restoring power to the network after an outage.

The huge scope of LFC in PS is the major motivation behind this research.

3. Literature Review

There are huge research have been done in the field of improving the performance of LFC based PS. This section has reviewed most relevant literature in this field related to proposed work. Diambomba Hyacinthe Tungadio et al [1]have aimed to maintaining equilibrium of power between linked locations and managing power flow in tie-lines using load frequency management. Since electricity cannot be stored in great quantities, its generation must always match the amount it is used. This formula served as the foundation for effective power management and highlights the requirement for additional controls when integrating energy from renewable sources into conventional power systems. There are many more controls in the existing literature, and Diambomba et al offers a review of conventional computers and controls that integrate machine learning techniques into conventional controllers.

Kumar, N.K et al [2]have described the use of fuzzy logic-based control of load frequency to artificial bee colony (also called ABC) efficiency in an island hybrid energy system model. An energy storage facility and a number of generating units made up the Island Integrated Electricity System that was taken into consideration for this study. An smart fuzzy logic device was developed using the PID's optimal control variables, which were derived from ABC. A Super Conductive Magnets Electricity Storage (SMES) System was used to enhance the characteristics (the authority & frequency) of an independent hybrids energy system. For wind turbines and generators powered by diesel, separate computers were used to regulate power production in order to balance demands (the amount change management). A comparison of energy and frequencies using a range of traditional and sophisticated control setups is provided. But tuning optimizer is difficult task.

Sameen ul haq ahmad et al [3]proposed the application of a fuzz logic-based regulator for control of load frequencies (LFC) and automated generation control (AGC) of two area nuclear power plants in an integrated power system. Furthermore, two domains are considering the use of a super magnet energy storage (SMES) unit. The application of SMES combinations stops the early decline in tie-line energy variance and deviations in frequency following a significant load disruption. The suggested SMES unit considerably enhances system efficiency, according to the simulation's findings. To do an impact study on the structure, the the initial values for the variables and operational load circumstances are changed. Namburi Nireekshana et al [4] had primary goal to efficiently regulate the LFC of an electric generator's electrical output at a specified location in response to variations, in order to keep tie-line load and system noise within predefined bounds. An FIS, or adaptable neuro-fuzzy inference structure, is a regulator that combines the advantages of fuzzy and neuronal networks. A comparison of Proportional-Integral-Derivative (PID)-based, artificial neural network (ANN), and Adaptive Neuro- Fuzzy Inference System (ANFIS)-based techniques shows that the proposed ANFIS control system works better than both PID and ANN controllers in reducing strength and variation in frequency in various regions of an integrated power system.

Syed Mahboob Ul Hassan et al [5] achieved frequencies dampening within a hybrid sunlight system, this study suggests constructing a partial-integral-defrencing PID controller and integrating a plug-in hybrid electric car (PHEV), on and a battery-powered energy storage system (BESS). Neural network models (ANN) are used to estimate the solar PV production with excellent precision, assuming that the inputs provided to the model include sunlight and cell temperatures. ANN is used to predict the fluctuation in load while taking into account the factors influencing the load. Using genetic approach, swarm particle optimization synthetic bee colony, and dragonfly algorithm, optimal values for each PID controller were determined by taking into account the total absolute errors (IAE), integrated squared error (the ISE), and integral period absolutely errors (ITAE) objective functions. Measurements were made of IAE, ISE, ITAE, rise a period of time settle time, maximum overestimation, and the highest frequency departure for efficacy and comparability.

DipayanGuha et al This article presents an effort to use the grey wolf optimum (GWO) approach to tackle the load frequency regulation (LFC) issue facing a connected electrical network that includes a standard PI/PID controller. To better validate the efficiency of the suggested method, the study has been broadened to three additional realistic strength structures: (i) two-area multi-units hydro-thermal strength system; (ii) two-area multi-sources energy system with thermal, water and gas generators; and (iii) three-unequal-area everything heat electrical system. The suggested approach is first implemented for two-area interrelated non-reheat thermal-thermal strength system.

Dynamic stability of the aforementioned systems is examined in the presence of the steam turbine's generating rate constraint (GRC), which is incorporated into the system modelling. Using an integral time compounded absolute variance (ITAE) based efficiency operation, the technique known as GWO improves the advantages of the controller. The efficacy of the suggested GWO method has been contrasted to other comparable meta-heuristic efficiency approaches that are available in the field for test systems that are similar, such as collection of mutation as well as crossover methods and variables in differential evolutionary theory (EPSDE), complete learning particles swarm efficiency (CLPSO), and others.

Sambit Dash et al This study presents a unique method for controlling the load frequency of a microgrid that combines a solar heating generation and photovoltaic system. The equipment's frequency is managed using a linear adaptable regulator that is based on the self-regressive average movement algorithm (NARMA). Such a controller seeks to manage and reduce variation in frequency brought on by variations in load. Additionally, an innovative metaheuristic method known as the Improved Whale Optimization Algorithm (MWOA) is employed to generate the best PID controller configuration for rate management. Lastly, a comparison of the WOA-tuned PID system, the traditional PID administrator, and the suggested NARMA L2 control is given.

Syed Mahboob Ul Hassan et al [8] achieve frequency attenuation in the hybrids solar electricity framework, this study suggests constructing a PID controller, and integrating a plug-in hybrid electric car (PHEV), which and an energy storage system for batteries (BESS). Artificially generated neural networks (ANN) are used to estimate the solar PV production with excellent precision, assuming that the inputs to the model include solar radiation and cell temperatures. ANN is used to forecast the fluctuation in load while taking into account the factors influencing the load. Employing the genetic algorithm, the particle swarm optimise (PSO) artificially bee colony, and dragonfly technique, the ideal parameters of the PID control function were determined by taking into account the integral absolute errors (IAE), integral squared error (ISE), & integral time relative error (ITAE) function objectives. Measurements have been made of IAE, ISE, ITAE, rising a period of time settlement time, peak overestimation, and the greatest frequency variation for efficacy and comparability.

Indrajit Koley et al [9] designed LFC used in the electrical system to guarantee zero error in steady state in multi-area composite energy systems. On the other hand, cyclic frequency deviation-induced fluctuations in load result in frequency faults and unplanned tie-line power. In order to project demand for loading and production using seasonal characteristics, a unique functional load projection technique is used, in which the goal function using the support vector regression method uses computing in parallel to accommodate the allowable error margin. Furthermore, it is challenging to estimate the response time variance under dispersed floating modes due to the uncertainty associated with active generation of energy in islands mode.

Therefore, a novel variations control system method has been suggested, in which the device controller anticipates an elevated customer demand space that exceeds the maximum threshold and separates that area up until the variance is corrected. The controller uses the rectangular range work to find the optimal magnitude appreciate from specific regions. The suggested approaches were used to model low tie-line authority, frequency range, and settlement time variations using the Simulink are environment.

Sharma, A et al]10\ brought on the growing amount of converter-based alternative power sources entering the grid results in fluctuations in grid frequency. A two-area energy system with several producing units has been equipped with a PID controller that uses swarm particle optimum (PSO) and virtual immobility (VI) control to address this issue. The degree of fluctuation and reaction time are enhanced as a result. This work uses an inverse control approach to simulate the VI, which regulates the energy storing device's electrical activity and supplies the electrical the system's momentum supports. The measurement of performance for PSO has become called the integral time measurement of error (ITAE). In addition, by including electric cars as vehicle-to-grid materials, the main source of frequency regulation is enhanced. In summary, a comparison study of the VI by PSO-PID management and traditional control (PI) has been conducted, along with a number of disturbances cases.Raj, T.D et al [11]have compared the dynamic properties of connected power networks with several types of producing sources, including thermal, hydroelectricity, and gas plants. Measurement of frequencies & tie-line energy are employed to improve the accuracy of the research.

The Bald Eagle Swallow search optimum (BESSO) method was applied to precisely tune the PID (proportional integral derivative) control gains. The eagle's & sparrows' traits were combined to build the BESSO algorithms. The effectiveness of BESSO is assessed by contrasting its results with those obtained using conventional methods. The results of this study show that the BESSO-PID regulator is successful in reducing systems error, as measured by Integrated Time Approximate Error (ITAE), the most significant criteria.

Diem-Vuong Doan et al [12] presented a unique LFC technique using fuzzy logic-based controllers akin to Particle Swarm Improvement (PSO) ~ PID. Among the best efficiency strategies is PSO. For every LFC suggested in this research, it uses to establish four scalability factors in the best possible way. In addition to RE sources like solar and wind electricity, a three-area energy system comprising a pumping location, non-reheat plants, & a reheating unit is taken into account. The management efficiency of the suggested approach is evaluated against that of the current controls for the same interrelated electrical system System that includes various instances of fluctuations in load including deviations and distinctive RE source limitations. The controllers investigated include genetic algorithms (GA), Microbes Hunting Improvement Algorithms (BFOA), A fraction Order-PID (FPID), and ambiguous logic-based PI controls.

Surya Prakash et al [13] have used PI controllers and artificial intelligence to evaluate the continuous operation of the load frequency management (LFC) for three area linked geothermal reheating power systems. The suggested approach involves the development of control methods for a three region linked hydro-thermal reheated electrical system employing a standard controller for PI, an artificially intelligent neural network (an ANN), and a controller based on fuzzy logic (FLC). Areas 1 and 2 of this article are made up of thermally reheat generators, whereas Area 3 is made up of hydro power plants. This suggested approach enhances the chaotic nature of the system by combining the most complex systems, such as the heating plant and reheated turbines and the water supply plant, in an integrated manner. Calculated microcontroller performance is obtained with the MATLAB and SI the course.

Deepak Kumar Soni et al [14] examines a resilient load frequencies control for a hybrid generation systems (H\GS) with two linked areas. Particles swarm optimum (PSO) and the genetic algorithm (GA) are used to determine the PID controller's settings. Four criteria—integral of total error (IAE), integrated of squared errors (ISE), integrated of time multiplication absolute error (ITAE), and integrated of time multiplication squared error (ITSE)—are used for comparing the efficiency evaluation of the improved controllers.

Aoqi Xu et al [15] stated that micro grids (MGs) are subject to a high degree of uncertainty and disruptions, including variations in demand, electrical power, and solar power, governance and handling of energy issues are complex. Therefore, the development of intelligent computers is required for these systems. In order to achieve automated frequencies and voltage oversight, this research employs a robust and optimum fuzzy regulator. Fuzzy logic strengthens the barrier versus unknowns and disruptions like radiation, variations in wind energy, and shifts in demand for electricity. Rising time, settlement time, overestimation, and the control system's tolerance to uncertainty and perturbations effects are among the relevant and useful parameters that the reintroduction controller employs.

Nour EL Yakine Kouba et al [16] introduced a PID controller-based fuzzy logical controllers (FLC) application for load frequencies management in a multi-area linked energy system. To find the best amounts for the controller's PID settings, fuzzy logic is used. The simulation is performed using a nine-unit, three-area modelling system, and the sudden responses resulting from step disruptions in load in areas 1, 2, and 3 are displayed. Suppressing any fluctuations in the tie-line flow of electricity and system noise is the key goal. The efficiency of the suggested approach is validated by comparing with the heuristics Powder Swarm Improvement technique (PSO) and the traditional Ziegler-Nichols methodology (Z-N).

S.B. Masikana et al [17] study reviews the whole history of LFC research, covering energy systems from the past, present, and future. This analysis takes into account conventional electrical system designs, how RESs are incorporated into conventional models, related limitations, eliminated LFC, using electrically powered gadgets, implementing battery storage, and LFC methods specific to micro-grids or multi-micro grids. This thorough literature analysis attempts to close the knowledge gap by tackling current issues, such RES growth uncertainty, and offering suggestions for future paths for energy systems LFC.

Thus the prime concern of this paper is to validate the tree area inter connected PS asked on FLC.

4. Proposed FIS Three Area LFC System

Theproposed block diagram of the three area ti line connected PS using hydro and thermal generators as validation model is shown in the Figure 3. It can be observed the FIS is used as the fuzzy controlsas feedback loop and provides the error control. The internal system diagram or model or FIS is shown in Figure 4.

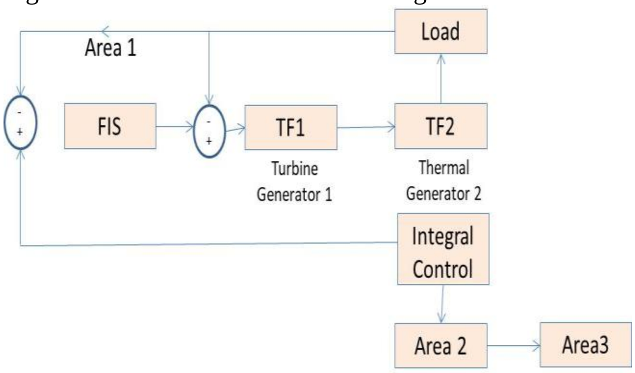

Figure 3. the proposed LFC based on FIS for three area til systems

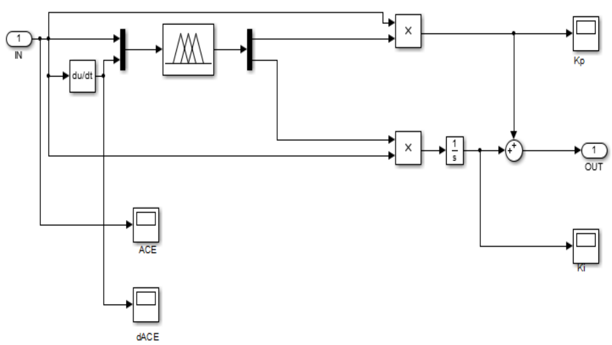

Figure 4 sub system model for FIS

It can be clear from the Figure 3 and 4, that the area control error (ACE) is managed automatically using the fuzzy set of rules. The integral and differential control is used for modelling.

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The proposed three are system model is shown in the Figure 5.

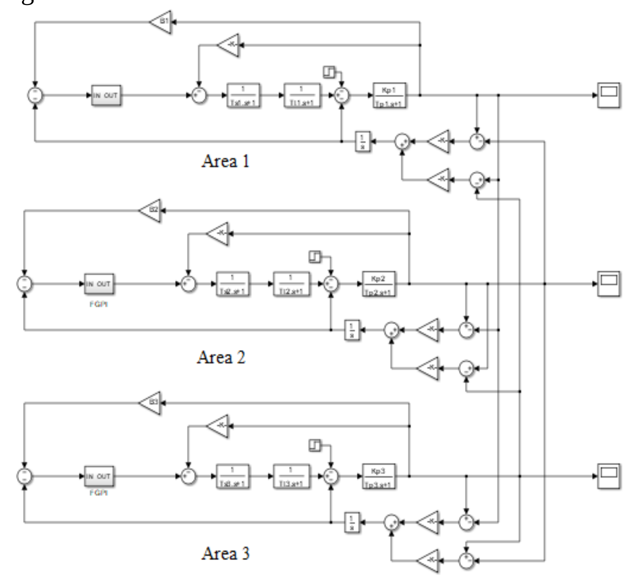
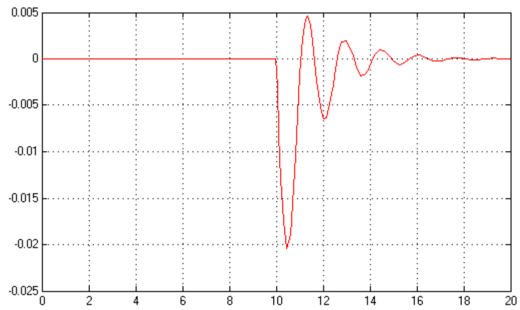


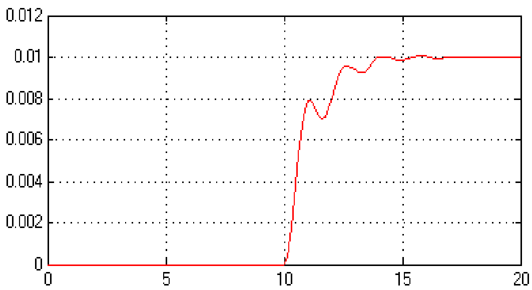
Figure 5 The proposed validated model of three area LFC

5. Results and Discussions.

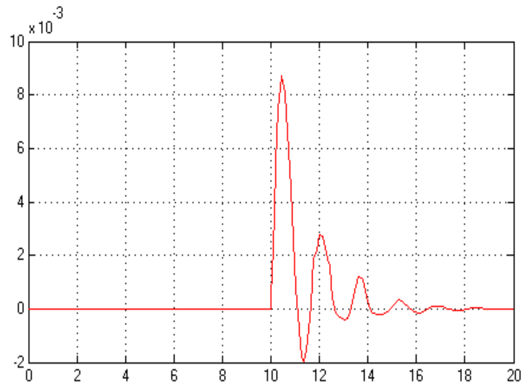
In this paper the basic results are validated for the three area PS using the FLC. The results of the three area frequency curves and ACE are shown in the Figure 6 a) to c) respectively to three areas



a) Frequency deviation for area 1



b) Frequency deviation for area 2



c) Frequency deviation for area 3

Figure6 The frequency deviation for proposed three area PS

The suggested three-area systems validation of frequency deviation and the impact of design parameters and the expansion of the solar PV system will be significant going forward. The peak overshot reduction is required for stable system performance.

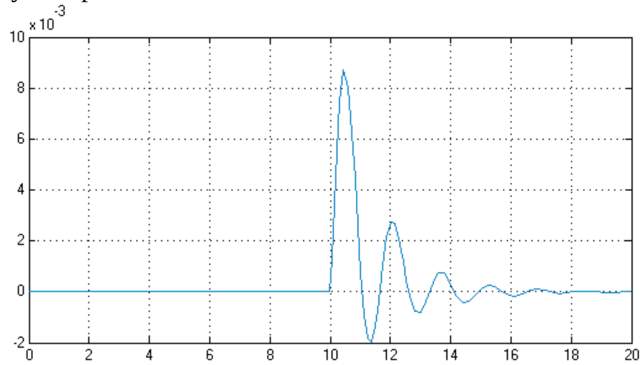


Figure 7 ACE for the third area systems output.

The ACE.is illustrated in Figure 7.

The simulation and modelling parameters are set for three areas as shown in Table 1.

Table 1 Parameters used for experiment

AREA 1	AREA 2	AREA 3
R1=2.4;	R2=2.4;	R3=2.4;
Ts1=0.08;	Ts2=0.08;	Ts3=0.08;
Tt1=0.28;	Tt2=0.28;	Tt3=0.28;
Tp1=18;	Tp2=18;	Tp3=18;
Kp1=120;	Kp2=120;	Kp3=120;
T12=0.06;	T21=0.06;	T31=0.08;
T13=0.08;	T23=0.06;	T32=0.06;
Ki1=.014;	Ki2=.014;	Ki3=.014;

The load is kept same for all area for validation. While generator speed is slightly high for area 3.

6. Conclusions and Future Scopes

Paper focused on maintaining equilibrium between the generation and consumption of power in linked power systems is an essential undertaking. As a conclusion, an electricity production management is a crucial technology that maintains the stability, dependability, and economic effectiveness of modern electrical systems. It is necessary for optimal producing performance, allowing for the integration of alternate power sources, and maintaining tie-line voltage and frequency within permitted ranges. This is where load frequency control, or LFC, comes in handy.

The LFC is necessary to ensure power sharing and preserve system frequency stability. The three areas interconnected power systems based on LFC have been assessed and verified in this article. The utilisation of the fuzzy influence system (FIS) is the foundation for the performance optimisation.

This paper has investigated the dynamic functioning of LFC using FIS, utilising model of three-area an interconnected hydro-thermal procedure PS. Phenomenon related to loaf-frequency, frequency-time, as well as power-time characteristics are used to measure and validate the performance. The impact of load, generator speed, and frequency variations has first been assessed in this paper

Future works

In the future, AGC will be combined with smart grid technologies to increase its capacity. This calls for the use of advanced sensors, networked communications, and instantaneous information data analysis.

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