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Load Frequency Control of a Two Area Network using Fractional PID Controller

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ABSTRACT

This paper simulates load frequency control (LFC) problem in a two-area power system using a traditional PID controller and a Fractional Proportional-Integral-Derivative (FPID) controller. The study aims to enhance the stability and performance of the power system by minimizing frequency deviations and maintaining the desired power exchange between the interconnected areas. The FPID controller is designed and implemented to account for the model's dynamic characteristics and disturbances. Using MATLAB/Simulink, a detailed model of the power system was created, including the generator, load, turbine, and governor dynamics, with the two areas interconnected via tie-lines. The FPID controller was tuned using a Genetic Algorithm (GA) to optimize its parameters, aiming to improve system stability and reduce frequency deviations caused by load changes. Comparative analysis with a traditional Proportional-Integral (PI) controller demonstrated that the PI controller effectively stabilized frequency deviations and minimized tie-line power fluctuations, reaching a steady state in approximately 20 seconds. However, the FPID controller, despite its theoretical advantages, struggled to converge to optimal gains within the simulation timeframe due to the computational complexity of tuning fractional parameters. The FPID controller outperformed the traditional PI controller, achieving a reduction in overshoot by 32%, a decrease in settling time by 28%, thereby highlighting the relevance of advanced controllers in modern power systems.it also underscores the challenges of implementing FPID controllers in practical applications without significant computational resources.

1. INTRODUCTION

Load Frequency Control (LFC) is an essential part of power system operation, tasked with maintaining the system frequency and ensuring the balance between power generation and load demand across interconnected areas. In a modern power system, especially one divided into multiple control areas, LFC plays a critical role in stabilizing the frequency within each area and managing the power exchanges between them. A modern power system is complex and sophisticated with multi area and diverse source of power generation. The control of electric energy with nominal system frequency and tie line power interchange within prescribed limits are very much important. The load frequency control plays important role in power pool by maintaining scheduled system frequency and scheduled tie line power in normal operation and during small perturbation [1].

Traditional LFC methods rely on Proportional-Integral-Derivative (PID) controllers due to their simplicity and effectiveness. However, the growing complexity of power systems, influenced by the integration of renewable energy sources and the need for improved stability and performance, has driven the adoption of more advanced control strategies [2]. From historical context the tuning methods of PID controller, traces back to the foundational work of Zeigler and Nichols in 1942, who introduced two classical methods for tuning PID controllers based on process reaction curves and frequency domain analysis, there's also the contributions of Astrom and Hagglund, who further refined these methods by recognizing the significance of the Nyquist curve in controller tuning [3].

Fractional Order PID (FPID) controller exhibits significantly better disturbance rejection capabilities compared to conventional PID controllers. This is particularly important in load frequency control, where disturbances can arise from sudden changes in load or generation. The FPID controller can effectively manage these disturbances, leading to a more stable and reliable power system operation [4].

Load frequency control (LFC) is a vital mechanism in power system operation that ensures the balance between electricity supply and demand, thereby maintaining the system's frequency within acceptable limits. As power systems evolve, particularly with the increasing integration of renewable energy sources like wind and solar, the dynamics of LFC have become more complex. Consequently, we must adapt to incorporate advanced control strategies to effectively manage frequency fluctuations and ensure system stability in the face of variable and intermittent generation patterns. This adaptation is crucial for maintaining reliability and performance in modern power systems characterized by high renewable source penetration [5].

One such advanced method is the Fractional Proportional-Integral-Derivative (FPID) controller, which extends the classical PID controller by incorporating fractional calculus. This allows for more flexible tuning of the controller parameters, providing enhanced robustness and better dynamic performance, particularly in systems with significant uncertainties and varying load conditions. In a two-area power system, each area is responsible for controlling its own frequency and managing the tie-line power flow between the areas [6]. The implementation of an FPID controller in such a system aims to improve the system's response to load changes and inter-area power exchanges, leading to more efficient and stable operation.

The paper is organized into the following sections: Section 2 introduces the literature review; Section 3 present methodology and design methodology and Section 4 presents simulation results and discussion. Finally, section 5 presents the conclusion.

2. LITERATURE REVIEW

[7]. The paper presents a comprehensive and innovative approach to Load Frequency Control (LFC) in power systems, particularly addressing the challenges posed by uncertain transmission delays and the integration of renewable energy sources. By developing a robust delay-dependent PI-based LFC scheme grounded in sampled-data control, the authors effectively ensure system stability and performance under varying operational conditions. The use of Lyapunov theory and linear matrix inequalities to establish stability criteria is a significant contribution, allowing for practical implementation in real-world scenarios. Furthermore, the introduction of the exponential decay rate (EDR) as a performance index enhances the robustness of the controller against parameter uncertainties. Overall, the paper not only advances the theoretical understanding of LFC but also provides a practical framework that can be readily applied to modern power systems, making it a valuable resource for researchers and practitioners in the field.

[8]. Stability problems discussed in the paper have significant implications for the operation and reliability of interconnected multi-machine power systems. As these systems approach their transmission limits, the risk of severe disturbances increases, which can lead to widespread blackouts and operational failures. The paper emphasizes that large rotor angle deviations, resulting from disturbances, can disrupt the balance between electromagnetic and mechanical torque in generators, causing oscillations that threaten synchronism. This instability not only jeopardizes the continuous supply of power to consumers but also poses challenges for system operators in maintaining grid security. Consequently, understanding and addressing these stability issues is crucial for ensuring the resilience and efficiency of modern power systems, particularly as they evolve to accommodate increasing demand and integrate renewable energy sources.

[9] Present an application of GOA to LFC in a two-area power system. The ultimate goal is the frequency stability of the system and net tie-line power exchange among interconnected areas within limits. The GOA tunes a multi-stage PDF controller in conjunction with a PI controller to optimize dynamic responses. Comparative studies carried out with other optimization algorithms, such as Salp Swarm Algorithm and Genetic Algorithm, showed that GOA outperformed these algorithms, improving the performance on overshoot, settling time, and frequency deviation. Among its important strengths are its oscillation-reducing capability; hence, the stability of the system is guaranteed under variable loading conditions. However, a small limitation observed was the computational cost of the GOA algorithm involved, especially in cases when large power systems were concerned and were to be dealt with nonlinearities. Further research may be done in order to enhance the algorithm at the cost of computational efficiency with no loss in performance. This study thus gives weight to how advanced optimization methods make the power system stable and points to the potential of GOA in future applications of LFC.

3. LOAD FREQUENCY CONTROL

As power systems evolve, particularly with the increasing integration of renewable energy sources like wind and solar, traditional control methods face significant challenges in maintaining this balance. Advanced control strategies, such as fractional order PID controllers, have emerged as effective solutions. These controllers provide improved disturbance rejection and robustness, making them particularly suitable for managing the complexities of modern power systems [10].

3.1 Power system stability

Power system stability is crucial for ensuring reliable and continuous electricity supply. It involves the study of how a power system responds to disturbances, such as sudden changes in load or faults. Stability refers to the ability of an electrical network to maintain a steady and synchronized operation after being subjected to disturbances [11]. Active and reactive power demands are never steady and they continually change with the rising or falling trend. Steam input to turbo- generators (or water input to hydro-generators) must, therefore be continuously regulated to match the active power demand, failing which the machine speed will vary with consequent change in frequency which may be highly undesirable since maximum permissible change in frequency is $\pm$ 0.5 Hz [11].

This includes Transient Stability which is the ability of the system to maintain synchronism when subjected to large disturbances, such as faults. It assesses whether the generators can maintain steady operation without losing synchronism.

Primary frequency control, involves governing the turbine speed to regulate the frequency of the power system. This is crucial for maintaining grid stability and ensuring the reliable operation of the power network [12].

3.2 Turbine speed governing system

The turbine speed governing system is essential for regulating the speed of turbines in power plants, which in turn controls the frequency of the generated power. The governing system works by adjusting the steam or water flow to the turbine based on the load demand and the system frequency [13].

The mathematical model of the turbine speed governing system is represented by a transfer function that relates the change in the governor valve position $\Delta Xg(s)$ to the change in turbine speed ($\Delta\omega$). A standard transfer function is:

$$G_{(s)} = \frac{\Delta x_{g(s)}}{\Delta \omega_{(s)}} = \frac{1}{T_s.s+1} \quad (1)$$

where $Ts \cdot s$ is the time constant of the system.

3.3 Single area load frequency control

Load Frequency Control (LFC) in a single-area system focuses on maintaining the system frequency within acceptable limits despite changes in load demand. The main objective of

LFC is to balance the power supply with the power demand in real-time by adjusting the output of the generators.

A single-area LFC system comprises several components, including the generator, governor, turbine, and load. The primary objective is to maintain the frequency (f) at its nominal value [14].

3.4 Governor model

The mathematical model for LFC involves the development of a block diagram representing the relationships between different components, such as the governor, turbine, and load. The key equation used is [14].

$$\Delta p_m(s) = \frac{-1}{R} \Delta f(s) \qquad (2)$$

where $\Delta Pm(s)$ is the change in mechanical power, R is the droop characteristic of the governor, and $\Delta f\,(s)$ is the frequency deviation.

The system can be represented by a transfer function that relates the frequency deviation to the load change.

3.5 Turbine model

The turbine converts the governor's mechanical input into electrical power. Its dynamics are represented by a first-order transfer function [14].

$$\Delta p_m(s) = \frac{1}{T_{ts}+1} \Delta p_g(s) \qquad (3)$$

$\Delta Pm(s)$ is mechanical Power, Tts is Turbine Time Constant

3.6 Generator and load model

The generator and load together form the power system, which has an inertia constant M and damping coefficient D. The relation between frequency deviation and power is:

$$M\frac{d\Delta f_{(t)}}{dt} + D\Delta f(t) = \Delta pm(t) - \Delta pd(t) \qquad (4)$$

$\Delta Pd(t)$ is change in load demand, M is inertia and D represents Damping Combining the above models, we get the block diagram representation of the single-area LFC. The overall transfer function relating the frequency deviation to load changes is [14].

$$\Delta f_{(s)} = \frac{1}{m_s + D} \cdot \frac{1}{T_{ts}+1} \cdot \left(-\frac{1}{R}\right) \Delta f_{(s)} + \frac{1}{m_s + D} \cdot \frac{1}{T_{ts}+1} \Delta pd_{(s)} \qquad (5)$$

The overall block diagram typically includes the governor, turbine, and power system inertia, forming a closed-loop control system [15].

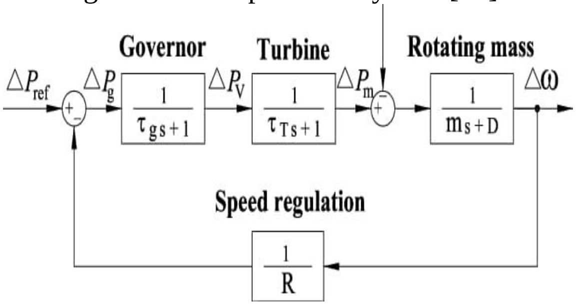

Figure 1. Block Diagram of isolated LFC

3.7 Control area concept

In power systems, a control area is defined as a region within which the operators have the ability to control the frequency and power flows across tie-lines to adjacent areas. Each control area operates under a common control system that monitors the area's generation and load balance, ensuring that the frequency deviations are minimized [16].

The concept of control areas is crucial for understanding multi-area load frequency control, where each area is responsible for maintaining its own frequency while also regulating power exchanges with neighboring areas. The Area Control Error (ACE) is a key metric used to assess the performance of each control area, calculated as:

$$ACE = \Delta p_{tie} + B.\Delta f \qquad (6)$$

where $\Delta Ptie$ is the deviation in tie-line power flow, B is the frequency bias, and Δf is the frequency deviation [16].

3.8 Two-area load frequency control and its modelling

In a two-area power system, the LFC problem becomes more complex due to the interaction between the areas. Each area has its own LFC loop, and the two areas are connected via tie-lines. The objective is to maintain the frequency in each area while also controlling the power flow on the tie-lines.

The mathematical model for two-area LFC involves the formulation of differential equations that describe the dynamics of each area's frequency and tie-line power exchange. The ACE for each area is calculated, and the control strategy aims to minimize these errors. The system is often represented by a set of coupled differential equations, where the frequency deviation in one area affects the tie-line power flow and, consequently, the frequency in the adjacent area [15].

1. Frequency Dynamics of Each Area: Each area has a similar dynamic model as the single-area LFC.

For Area 1:

$$M_1 \frac{1}{dtd\Delta f_1(t)} + D_1 \Delta f_1(t) + \Delta pm_1(t) - \Delta pd_1(t) - \Delta p_{tie}(t) \quad (7)$$

For Area 2:

$$M_2 \frac{1}{dtd\Delta f_2(t)} + D_2 \Delta f_2(t) = \Delta pm_2(t) - \Delta pd_2(t) - \Delta p_{tie}(t) \quad (8)$$

$\Delta Ptie(t)$ is tie-line power deviation

2. Tie-Line Power Exchange: The power exchange on the tie-line is proportional to the difference in frequencies between the two areas:

$$\Delta p_{tie}(s) = \frac{2\pi T_{12}}{s}(\Delta f_1(s) - \Delta f_2(s)) \quad (9)$$

where $T12$ is the synchronizing coefficient, reflecting the strength of the interconnection.

3. Control Law: The control law for each area is designed to minimize ACE:

$$p_{g1}(s) = -\frac{1}{R_1}[\Delta f_1(s) + \frac{ACE_1(s)}{B_1}] \quad (10)$$

$$\Delta p_{g2}(s) = -\frac{1}{R_2}[\Delta f_2(s) + \frac{ACE_2(s)}{B_2}] \quad (11)$$

3.9 Genetic algorithm

Genetic Algorithm is a natural selection-driven, genetics-inspired optimization technique. Individuals in the population represent a solution encoded into a chromosome, usually a binary string. The algorithm operates on successive generations to evolve the population towards an optimal solution with operations such as selection, crossover (recombination), and mutation

It starts by generating a random population of N individuals (chromosomes). Here, each individual $X_I$represents a solution in the search space:

$$p(0) = \{x_1(0), x_2(0), \dots x_N(0)\} \quad (12)$$

$X_I(0)$ is the chromosome of the i_{th} individual at generation (t=0). In this way, the initial population ensures good diversity of solutions.

$$P(X_I) = \frac{f(x_i)}{\sum_{j=1}^{N} f(x_j)} \quad (13)$$

At every generation, the fitness of each individual is calculated. The selection mechanism then works in favor of individuals with higher values of fitness. That is, the fitter the individual, the higher the probability of selection to reproduce. The probability $p(x_i)$ of selecting an individual $x_i$is proportional to its fitness f(x_i) Where f(x_i) is the fitness value of the i_{th} individual. These selected individuals then become the parents to generate offsprings via crossover.

A random crossover point K is selected and parts of chromosomes of the parents are exchanged to result in the child X_{Child} as in equation (14)

$$X_{child} = [X_{parent}(1:X) \,|X_{parent2}(k+1:L)] \quad (14)$$

where L is the length of the chromosome and K is the point at which the crossover takes place. This ensures the offspring will combine something from both parents and might turn out to be a better solution. The purpose of mutation is to provide random variations in the genes of the offspring for diversity in the population and to avoid precocious convergence. In the case of binary encoding, mutation flips the value of a randomly chosen bit in the chromosome as in equation (15)

$$X_i^{mutated}(j) = 1 - X_i(j) \quad (15)$$

Where j is the index of the randomly chosen gene and the mutation rate P_m controls the probability of mutation. This will guarantee that the Algorithm does not get stuck in a part of the

solution space but will also explore new arears. Once crossover and mutation are performed, the newly generated population is again evaluated for their fitness. The fitness function quantifies how good an individual is with respect to the optimization problem being addressed. The fitness score will determine the selection of individuals to contribute in the next generation. It then evolves the population for many generations until a stop condition is reached which is usually a predefined number of generations or if an acceptable solution is found with regards to its fitness value. The best individual is selected from the population to yield the optimal solution.
This will ensure that the GA yields the optimal among those solutions it finds after going through all iterations of the population evolution process.

4. METHODOLOGY

This study focuses on the design of a two area Load Frequency Control Model using Fractional PID controller through the use of MATLAB/SIMULINK. A single area LFC network is first developed then integrated with a tie-line and the second LFC network, for an optimized model a Fractional PID controller is adopted to provided required control action.

4.1 Designing an appropriate controller

To attain stability our model requires a controller, A PID (Proportional-Integral-Derivative) controller is a crucial component in control systems, widely used for its ability to regulate system outputs to desired levels with precision. The PID controller adjusts the system's response based on the error between the desired setpoint and the actual output, using proportional, integral, and derivative actions to minimize this error over time. Tuning a PID controller involves setting these three parameters to optimal values, a process that can be complex due to the need to balance responsiveness and stability. In Simulink, tuning can be done using automated tools like the PID Tuner, which provides a graphical interface to adjust parameters and immediately see the effects on system performance. Alternatively, manual tuning methods, such as Ziegler-Nichols or trial-and-error, can be employed, allowing for fine-tuning based on specific performance criteria like overshoot, settling time, and steady-state error. The choice of tuning method depends on the complexity of the system and the desired control objectives.

The fractional order PID (FPID) controller is a type of PID controller where the derivative and integral orders are fractional rather than integer numbers. In traditional PID controllers, incorporating the concept of fractional calculus is disallowed, only for integer values. However, in FPID controllers, these orders can take fractional values, providing control over the system dynamics. The FPID controller consists of five parameters: proportional gain (kp), integral gain (ki), derivative gain (kd), integral order (λ), and derivative order (μ). By adjusting these parameters, the controller can be optimized to achieve desired system performance.

The tuning of an FPID controller in Simulink involves similar steps to tuning a traditional PID controller, but with additional complexity due to the fractional parameters. Techniques such as optimization algorithms, genetic algorithms, or heuristic methods are often used to find the optimal values for proportional gain, integral gain, derivative gain, λ, and μ. After installing Appropriate library, you can find the FPID block in Library>FOMCON Toolbox>Fractional PID Controller.

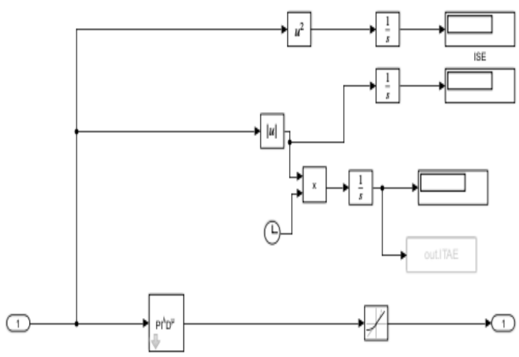

Figure 2. Setting Up FPID Tools box for Genetic Algorithm Tuning

In our model, the Genetic Algorithm (GA) optimization process involves a few key steps. Initially, a set number of variables to be optimized (in this case, 5) is defined, along with their lower and upper bounds. The GA operates within these bounds to find the optimal values for the variables. The process begins with a population of potential solutions, which evolve over generations. For each generation, the algorithm evaluates the fitness of each solution using an objective function, in this case, the optimization function, which simulates a model and calculates a cost based on a performance metric like the Integral of Time-weighted Absolute Error (ITAE).

Through selection, crossover, and mutation operations, the GA refines the population, gradually improving the solutions towards the optimal set of PID parameters. The optimization settings, such as the number of generations and population size, control the balance between exploration and exploitation in the search space. The result is a set of optimized parameters that ideally provide the best system performance according to the defined cost function. The process can be visualized using plotting functions that show the evolution of the best solution over generations.

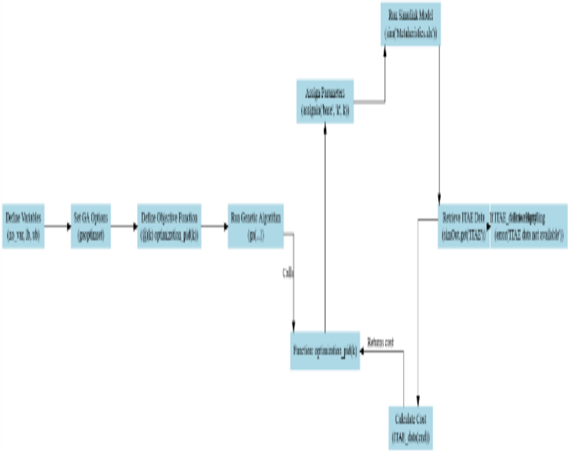

Figure 3. Fractional PID Block diagram

Implementing the blocks described in this section enables us to simulate the frequency deviation and mechanical power of both generators, with appropriate controller gains the deviation from required frequency of 50Hz should be minimal and close to Zero.

4.2 SYSTEM DESCRIPTION

Figure 3 presents a two-area interconnected power network. In a two-area power system, each area is responsible for controlling its own frequency and managing the tie-line power flow between the areas [17] and it achieves this by using different control loops for each area. Each area consists of an individual generating unit and the two arears are interconnected via tie lines which manage the synchronization between them leading to efficient power exchange. The interaction between the arears is represented by the transfer function ($2\pi T/s$),

Each area contains primary components such as the governor, turbine, and power system dynamics and they are modeled using first-order transfer functions. The components ensure that the system responds correctly to load changes and also maintains a steady frequency

Symbols used with suffix 1 refer to area 1 and those with suffix 2 refer to area 2. The figure demonstrates the complete model of the system, with Kg1, Kg2 representing the gains of the governors in areas 1 and 2 respectively and Tg1, Tg2 represent the time constants of the governors in areas 1 and 2 respectively. The gains of the turbines of the two arears are also represented by Kt1 and Kt2 with Tt1 and Tt2 also representing the time constants of the two turbines. Kp1, Kp2 and Tp1, Tp2 represent the gains and time constants of the power system in the two arears.

The speed regulations which are due to governor action are denoted by R1 and R2. These parameters help in managing power sharing between areas in response to changes in frequency. The resulting power deviations in area 1 and 2 denoted by $\Delta Pd1$ and $\Delta Pd2$ undergo comparison and corrections by means of control loops Δ represent the reference power changes in areas 1 and 2, while represent the resulting power deviations in each area. These deviations are compared and corrected through the control loops.

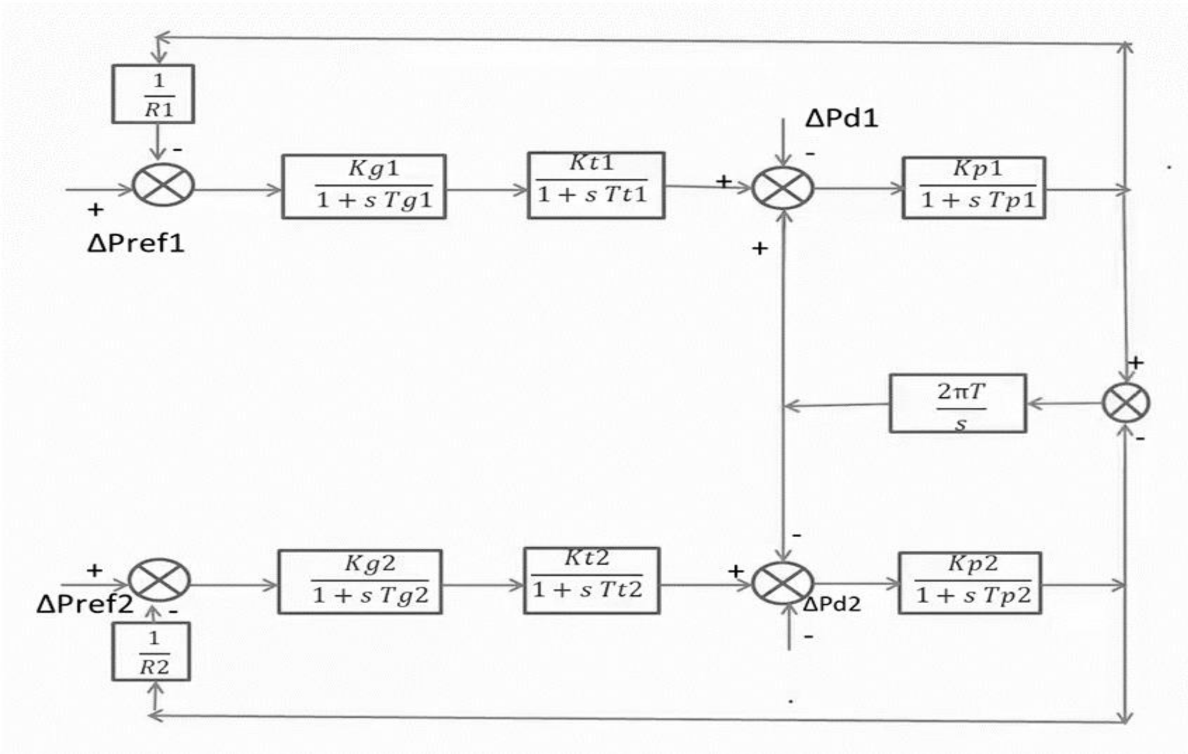

Figure 4. A Two Area LFC Network

4.2.1 Fractional PID controller

This controller is an extension of the traditional PID controller. The FOPID transfer function is given by:

$$c(s) = k_p + k_i s^{-\lambda} + k_d s^{\mu} \tag{16}$$

Where the proportional gain is represented by Kp, the integral gain is represented by Ki is, Kd is the derivative gain, μ is the fractional part of the derivative gain and λ represents the fractional part of the integral gain. The FPID controller consists of five parameters: proportional gain (kp), integral gain (ki), derivative gain (kd), integral order (λ), and derivative order (μ). By adjusting these parameters, the controller can be optimized to achieve desired system performance. The structure of FOPID controller is given in fig2

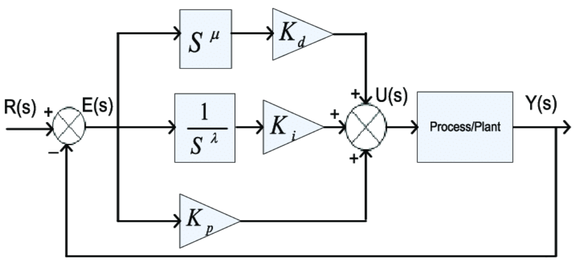

Figure 5. structure of FOPID controller

5. RESULTS AND CONCLUSION

Our simulated system as described are two parallel units with a nominal frequency of 50Hz. The result of this paper describes the new steady state frequency, the frequency deviation and the change in tie-line flow when there is a load change of 187.5MW in area 1.

For a load change of 187.5MW, the per unit load change in area 1 is: 0.1875pu

5.1 Performance assessment of the two-area network without controller.

The per unit steady-state frequency deviation for the two units is -0.005pu shown in the figure

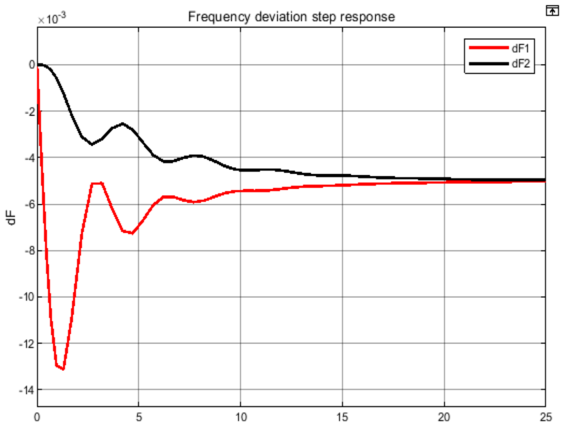

Figure 6. frequency deviation without Controller

Thus, steady state frequency deviation in Hz is $\Delta f = (-0.005)(50) =$ -0.25 Hz and the new frequency is $f = f_0 + \Delta f$ = 49.75.

The change in mechanical power in each area is 0.1pu represented as dP1 for mechanical power in area one and 0.0790pu represented as dp2. Hence, the true mechanical power is 100 MW for unit 1 and 79MW for unit 2 at the new operating frequency 49.75. the total change in generation is 179MW which is 8.5MW less than 187.5MW load change because of the change in loads due to frequency drop.

The change in area 1 load in ΔwD_1 = (-0.005*0.6) = -0.003 pu (-3.0 MW) and change in area 2 load is ΔwD_2 = (-0.005*0.9) = -0.0045 pu (-4.5MW), thus the change in total load is -7.5MW.

The tie-line power flow ΔP_{12} is represented by dP12 is -0.0837pu translated to -83.7MW, this means 84.5MW flows from area 2 to area 1, 80MW comes from the increased generation in area 2, and 4.5MW comes from the reduction in area 2 load due to frequency drop.

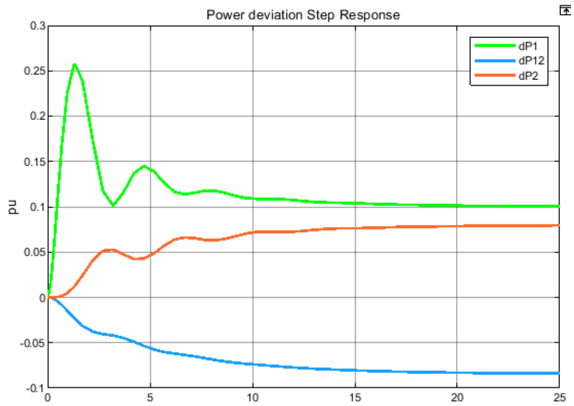

Figure 7. Power deviation without Controller

The power deviation step response graph shows how the system reacts to a sudden 187.5 MW load increase in Area 1. Initially, the power deviation in Area 1 (green line) spikes due to the load change, causing an overshoot before the control system begins to stabilize. The tie-line power deviation (orange line) shows that Area 2 initially transfers power to Area 1 to help balance the frequency, which results in a negative power deviation in Area 2 (blue line). Over time, the oscillations in both areas reduce, and the system gradually returns to steady state, where the power deviations in both areas and the tie-line approach zero, indicating that balance has been restored.

5.2 Performance assessment of the two-area network with controller.

The controller for the two-area system is used as actuating signals to activate changes in the reference power setpoints, and when steady state is reached, ΔP_{12} and Δw will be zero. The integrator gain is set small enough so as not to cause the area to go into chase mode.

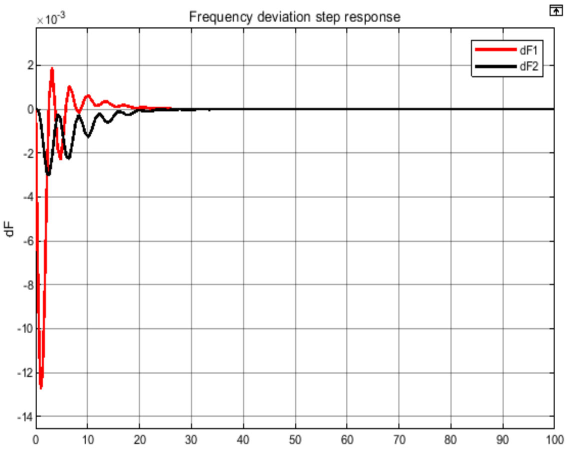

Figure 8. frequency deviation with PI Controller

As seen in figure 3, With the PI controller in place, the system's performance improves significantly. Initially, when the load in Area 1 increases, there is a frequency deviation, but thanks to the PI controller, the system quickly adjusts and brings the frequency deviation to zero. The PI controller works by integrating the error over time, which eliminates steady-state frequency deviations, ensuring that the system maintains a nominal frequency (e.g., 50 Hz) in both areas.

Moreover, the tie-line power deviation, which initially helped transfer power between the areas to stabilize the frequency, also reduces to zero. This means that the system has achieved balance between the generation and load in each area. The increase in load in Area 1 is fully compensated by a corresponding increase in generation in that area, negating the need for power flow through the tie-line. The overall response shows that the PI controller not only minimizes frequency deviations but also optimizes the generation response to meet load changes, ensuring stable and efficient operation of the interconnected power system with a settling time of around 20 seconds.

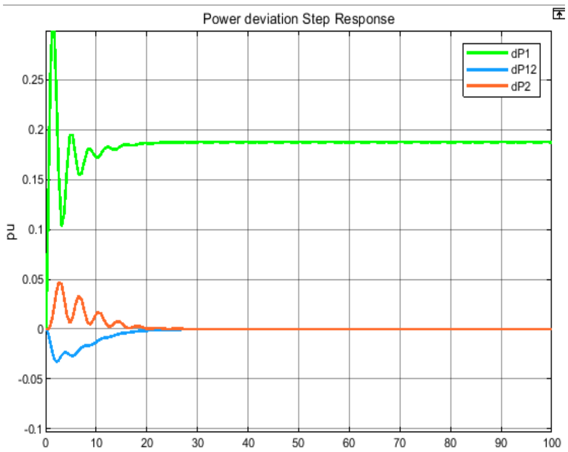

Figure 9. Power deviation with PI Controller

In this power deviation step response graph, the system's behavior is influenced by a Proportional-Integral (PI) controller, which is designed to improve the stability and speed of the system's response. Compared to the previous graph, the green line representing the power deviation in Area 1 (dP1) shows a quicker settling time, with reduced oscillations and more rapid stabilization around the 0.15 per-unit (pu.) mark. This indicates that the PI controller has effectively minimized the overshoot and oscillations in response to the 187.5 MW load change in Area 1. The power deviation across the tie-line (dP12) and in Area 2 (dP2) also exhibit much smaller oscillations and settle faster, with both deviations approaching zero more smoothly. The PI controller's integral action eliminates steady-state errors more effectively than a standard controller, leading to a more balanced and stable system response over time.

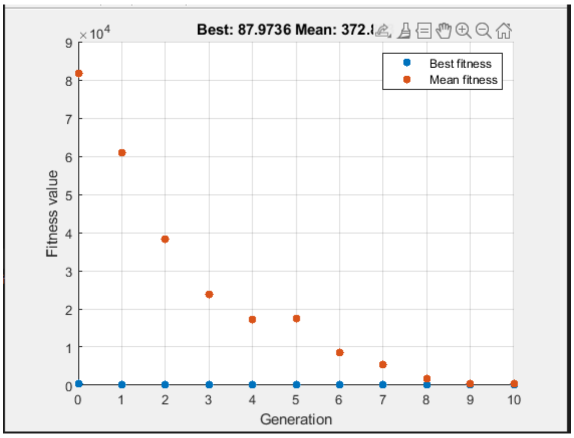

Figure 10. Fractional PID results

To demonstrate the effectiveness of FPID, we implemented a Genetic Algorithm to tune our Fractional PID controller, as described in the methodology, the simulation ran with a population size of 50 and Generation of 10, which lead to 500 iterations in search of the best fit in of PID controller Results from FPID, from figure 4.5, The Blue Dots describe the Best Fitness, these points represent the best fitness value found in each generation. The best fitness value typically decreases or stabilizes over time, indicating that the algorithm is finding better solutions as it progresses. The Red Dots describe the Mean Fitness, these points represent the average fitness value of the population in each generation. the best fitness value started high (around 87,000) and dropped significantly, stabilizing around 87.9736. This indicates that the genetic algorithm has found a solution over the generations. The mean fitness also decreased significantly, indicating that the overall population of solutions improved in quality, but there was still a wide range of fitness values in the population.

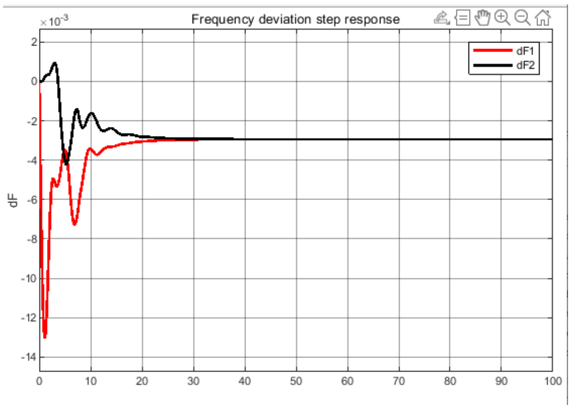

Figure 11. Results of FPID Simulation

However, results from model as shown in figure 7 did not converge at zero but about 0.003 after generations, which can be described as a poor response, this suggest that the optimum gains for the model have not yet been found, the FPID requires heavy computing power to find gains due to increase number and possibility of gains, the ITAE for our model never converged in good time, which suggested increased search time, higher computing device and the use of a more robust algorithm, implementation of the algorithm or a different algorithm.

6. CONCLUSION

In this paper, we have demonstrated the usefulness of load frequency control for two area network generating power system, the relevance of control action in load frequency control and important concepts that back the simulation were also discussed.

The results of the simulations indicate that the implementation of a PI controller significantly improves the frequency stability and power deviation in a two-area power system. The system without a controller exhibits a frequency deviation of -0.25 Hz and a tie-line power flow deviation of -83.7 MW. With the PI controller, the steady-state frequency deviation is reduced to zero, and the tie-line power flow deviation is minimized, with a settling time of approximately 20 seconds thus demonstrating the effectiveness of the PI controller in maintaining system stability.

The use of GA in tuning the FPID controller, with the Integral of Time-weighted Absolute Error (ITAE) as the objective function, proved challenging as the ITAE did not converge to zero within a reasonable timeframe. This indicates the need for either a more efficient implementation of the algorithm or the consideration of alternative optimization methods that are less computationally intensive. The use of PID controllers showed more Benefits over FPID controllers in the context of this projects because of its simplicity and reduced computational demands. Traditional PID controllers are well-understood and easier to tune, either manually or with automated tools.

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