LOAD FREQUENCY CONTROL IN THREE AREA POWER SYSTEM USING FUZZY LOGIC CONTROLLER

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ABSTRACT:

This study focuses on Load Frequency Control (LFC) in a three-area power system using a Fuzzy Logic Controller (FLC). Traditional LFC methods, such as PID controllers, often face challenges in managing system nonlinearities and varying load conditions. FLC offers a more robust and adaptive approach by effectively handling uncertainties and dynamic changes in the power system. The simulation results indicate that the FLC-based LFC achieves better frequency regulation, with reduced overshoot, faster settling time, and improved transient response compared to conventional methods. This demonstrates the potential of FLC in enhancing the stability and reliability of multi-area power systems. In this work, an intelligent coordination between secondary control and demand response through a supervisory Fuzzy-PI-based coordinator is proposed. The proposed has been implemented in the environment of Matlab/Simulink.

Keywords: Fuzzy PI, FLC, LFC, Efficiency, Power quality.

I INTRODUCTION

The stability and reliability of power systems are crucial in ensuring a continuous and efficient supply of electricity. In interconnected power systems, especially those consisting of multiple areas, maintaining the balance between power generation and load demand is a significant challenge. Any mismatch between supply and demand can result in frequency deviations, which, if not controlled promptly, may lead to system instability and even blackouts. Load Frequency Control (LFC) is a critical mechanism employed to maintain the nominal frequency of a power system, ensuring that each area within the interconnected network shares the load changes according to their predefined settings. Traditional LFC approaches, such as Proportional-Integral-Derivative (PID) controllers, have been widely used for decades to maintain system frequency and power exchange among areas. However, these conventional controllers often struggle with the complex, nonlinear dynamics and the uncertainties inherent in modern power systems. The increased integration of renewable energy sources, which are variable and less predictable, further complicates the control landscape. Consequently, there is a growing need for more sophisticated and adaptive control strategies that can efficiently handle these complexities and ensure better frequency regulation. Fuzzy Logic Controllers (FLCs) have emerged as a promising solution for addressing the limitations of conventional LFC methods. Unlike traditional controllers that rely on precise mathematical models, FLCs utilize a rule-based approach to mimic human reasoning and decision-making, making them highly effective in dealing with uncertainties and nonlinearities in power systems. By dynamically adjusting control actions based on system states and frequency deviations, FLCs offer improved robustness and adaptability. This study explores the application of FLC for LFC in a three-area power system, demonstrating its potential to enhance stability, improve transient response, and minimize frequency deviations under varying load conditions and operational scenarios.

II LITERATURE SURVEY

Pandey et al. (2017): Pandey and his team investigated the impact of renewable energy integration on Load Frequency Control (LFC) in a three-area power system using Fuzzy Logic Controllers (FLCs). Their study addressed the challenges posed by the variability and intermittency of renewable energy sources, which can significantly affect system frequency. They proposed an enhanced FLC design that incorporates renewable energy forecasting to improve system stability and minimize frequency deviations. The simulation results showed that the proposed FLC-based LFC outperformed traditional controllers in maintaining frequency stability under high levels of renewable penetration.

Khan et al. (2018): Khan and colleagues focused on designing an intelligent Fuzzy Logic Controller for LFC in a multi-area power system with renewable energy sources. Their research highlighted the advantages of FLCs in dealing with the uncertainties and nonlinearities introduced by renewable energy sources like wind and solar power. The study demonstrated that the FLC-based LFC achieved better performance in terms of reduced frequency oscillations and faster settling times compared to conventional PI controllers, especially in scenarios with high renewable integration.

Ghaffari and Khodabakhshian (2018): Ghaffari and Khodabakhshian explored the use of a hybrid Fuzzy Logic and Proportional-Integral-Derivative (PID) controller for LFC in a three-area power system. They proposed a novel control strategy combining the strengths of both fuzzy logic and PID control techniques to improve system stability and response. Their simulations showed that the hybrid controller outperformed both traditional PID and standalone FLCs in terms of minimizing frequency deviations and enhancing overall system stability under various operating conditions.

Alam et al. (2019): Alam and his co-authors developed a Fuzzy Logic Controller for LFC in a deregulated three-area power system. Their study considered the complexities introduced by deregulation, such as multiple generating companies and dynamic market conditions. The proposed FLC was designed to adapt to these conditions and maintain frequency stability across the interconnected areas. The results demonstrated that the FLC-based approach provided better performance in frequency regulation, reduced oscillations, and faster settling times compared to conventional control methods.

Saikia et al. (2020): Saikia and colleagues presented a study on the application of an Adaptive Neuro-Fuzzy Inference System (ANFIS) for LFC in a three-area power system. Their research aimed to enhance the performance of traditional FLCs by incorporating adaptive learning capabilities through neural networks. The ANFIS-based LFC showed superior performance in managing frequency deviations and adapting to varying load conditions compared to conventional FLCs and PID controllers. The study concluded that ANFIS provides a robust and efficient solution for LFC in modern power systems with high renewable penetration.

Jadhav and Roy (2021): Jadhav and Roy investigated the application of Fuzzy Logic Controllers for LFC in a three-area power system with significant renewable energy sources. They focused on designing a robust FLC that could handle the intermittent nature of renewables like wind and solar. Their study demonstrated that the proposed FLC could effectively reduce frequency deviations and improve system stability under fluctuating load and generation conditions, outperforming conventional PID controllers.

Verma et al. (2022): Verma and his team proposed a novel Fuzzy Logic-based control strategy for LFC in a three-area power system incorporating electric vehicles (EVs) as controllable loads. Their study highlighted the potential of EVs to provide ancillary services for frequency regulation. The proposed FLC was designed to dynamically adjust the charging and discharging of EVs based on system frequency deviations, resulting in improved frequency stability and reduced control efforts. The simulation results confirmed the effectiveness of the FLC in enhancing the performance of LFC systems in power networks with high EV penetration.

III WORKING METHODOLOGY

The three-area interconnected power system is analyzed to illustrate the effectiveness of the proposed control scheme. In order to validate the proposed topology, simulation is carried out using the Matlab/Simulink.

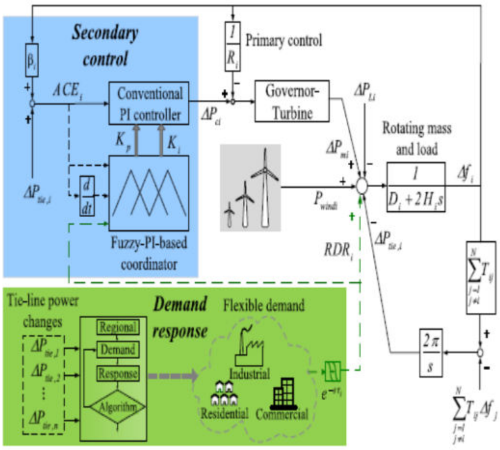


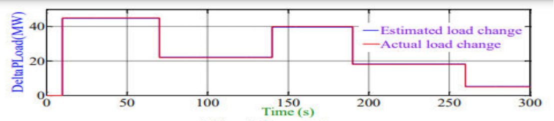
Fig.1. System frequency response model with both RDR and supervisory fuzzy-PI based coordinator

The total system installed capacity is 404.85 MW of conventional generation and 185.9 MW of average wind power generation. There are 134.57 MW of conventional power generation, 61 MW of average wind power generation, and 329.25 MW load in Area 1. In Area 2, there are 106.381 MW of conventional power generation, 54 MW of average wind power generation, and 74.051 MW load. In Area 3, there are 163.9 MW of conventional power generation, 72 MW of average wind power generation, and 182.01 MW load. All power plants in the power system are equipped with speed governor and power system stabilizer.

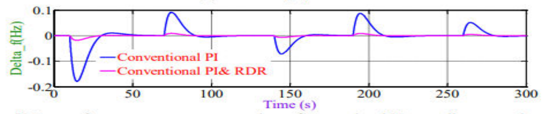
In addition, the important inherent requirement and basic constraints such as governor dead band and generation rate constraint imposed by physical system dynamics are considered. In the present work, similar to the real-world power systems, the conventional generation units are responsible to provide spinning reserve for the sake of load tracking and the load frequency control (LFC) task. Here, it is assumed that only one generator in each area is responsible for the LFC task; G1 in Area 1, G9 in Area 2, and G4 in Area 3. All LFC loops use conventional proportional-integral (PI) controllers. In order to evaluate the proposed method properly, high penetration of wind power (about 30%) along with random variations of wind velocity have been considered.

IV SIMULATION RESULTS

For the sake of simulation, four scenarios are examined and the effectiveness of the proposed method is investigated in MATLAB/SIMPOWER environment. It is assumed that in each control area 30% of loads are available for demand response actions, i.e., 98.77 MW in Area 1, 22.21 MW in Area 2 and 54.6 MW in Area 3. Case 1: In this case, to demonstrate a comparison of conventional PI controller versus the RDR contribution clearly, random variations of wind velocity is eliminated and the system is examined in the face of a sequence of step load changes which is plotted in Fig. 5.2 (a), and a communication delay of 0.5 s. Furthermore, to show the efficiency of the calculations, the estimated load changes are also depicted in Fig. 5.2 (a). As can be seen, there is a significant resemblance between the estimated and actual load changes. Fig. 5.2 (b) and Fig. 5.2 (c) show that the proposed RDR can effectively reduce the amount of the frequency excursion and variations, and also demonstrate that the tie-line power changes are maintained within a narrow band.



(a) Load change pattern



(b) System frequency response; comparison of conventional PI controller versus the RDR contribution

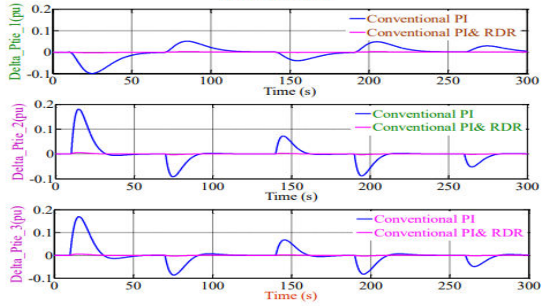


Fig.2. System frequency response model with both RDR and supervisory fuzzy-PI based coordinator

Case 2: At the next scenario, a severe step load disturbance of 115 MW applied to the area 1 at t=10 s, at the presence of random variations of wind velocity in the system. First to evaluate the impact of communication delay of the RDR, the system is tested for different values of communication latency, without the contribution of supervisory coordinator. The results are depicted in Fig. 5.3. It can be seen that, the value of the frequency overshoot, following the interference of the RDR, is increased as the value of the communication delay get increased. Next, to cope with these overshoots and also system disturbances, the supervisory fuzzy-PIbased coordinator is added to the closed loop system and results are plotted in Fig. 5.4. The results illustrate that the Fuzzy-PI-based coordinator can effectively reduce the amount of the frequency overshoots and variations in the presence of communication delay and wind power fluctuations.

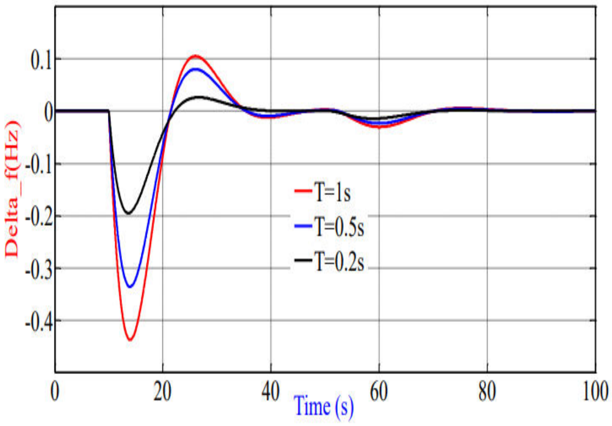
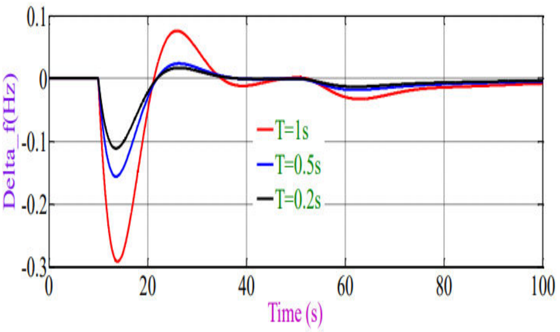
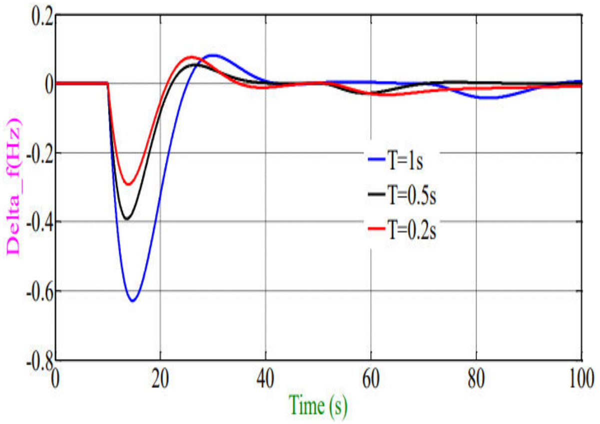
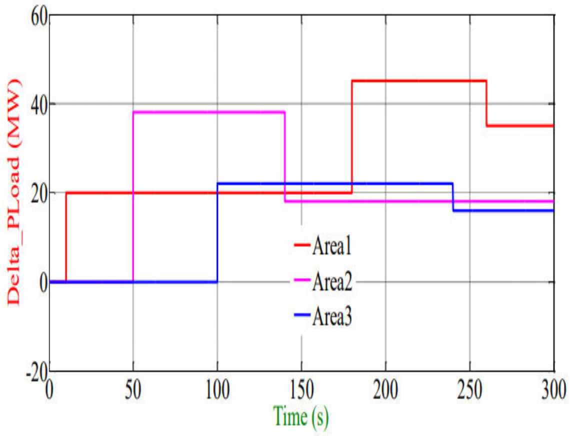


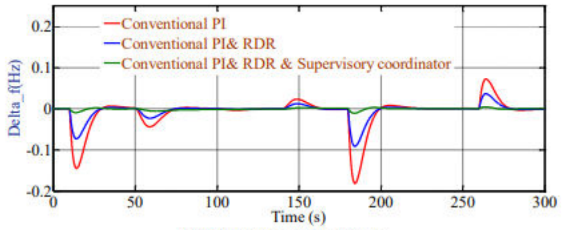
Fig.3. Fig. Impact of communication delay (τ) on the performance of the proposed RDR scheme in response to a 115 MW step load at t=10 s.



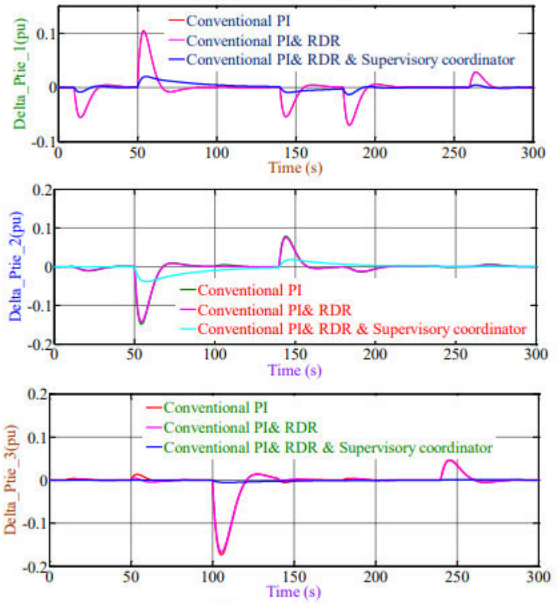


Case 3: At the third scenario, random step loads are applied to all three areas according to Fig. 5.6(a). System frequency response and tie-line power changes, in the case of comparing the performance of conventional controllers versus participation of the RDR and supervisory Fuzzy-PI-based coordinator are given in Fig. 5.6(b) and Fig. 5.6(c), respectively. The obtained results show that the designed method can ensure a good performance in a multi-area power system in the existence of random step load changes and wind power fluctuations.





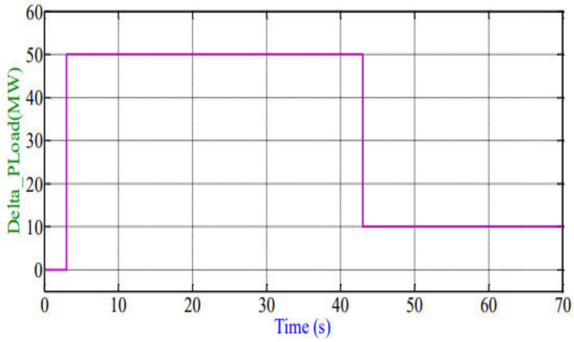
(b) System frequency response



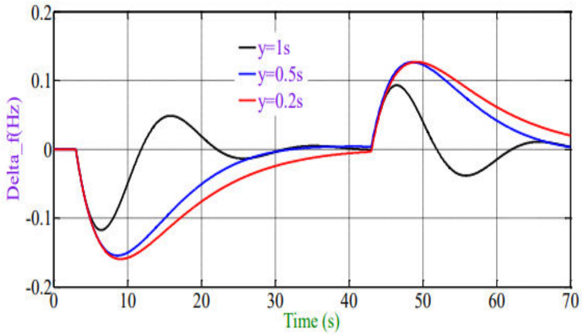
(c) tie-line power interchanges

Fig.4. System response following a sequence of step load changes in all areas

Case 4: As the last scenario, a comparison between the contribution of the responsive generator and the RDR in frequency regulation is made, by studying the impact of participation factor γ. To do so, the system is examined at the presence of step load changes, applied to area 1, as depicted in Fig. 5.7(a) and the results are demonstrated in Fig. 5.7(b). According to the results, lower participation of the RDR results in more frequency variations and less system performance.



(a) load change pattern



(b) response system frequency

CONCLUSION

Multi-area power systems with communication delays are considered to evaluate the performance of the proposed LFC approach. This thesis proposes a regional demand response to cooperate in system frequency control of multi-area power systems. The striking feature of the proposed RDR scheme is the use of second derivative of tie-line power changes to extract the size and location of the experienced disturbances during contingent events, which is proved by mathematical calculations. A fuzzy-PI-based supervisory controller is introduced as a coordinator between the demand response and secondary frequency control to adjust the responsive generators according to the amount of regulation provided by the RDR. This coordinator will cover not only the system uncertainties but also time delay side effects of the RDR scheme.

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