Chapter - 10
Load Frequency Control of Two Area Interconnected Power System

Authors

P. Marimuthu
Professor, Department of EEE, Malla Reddy Engineering College, Hyderabad, Telangana, India

Agalya V
Professor & Associate Head R&D, Department of EEE, New Horizon College of Engineering, Bengaluru, Karnataka, India

J. Kumaresan
Associate Professor, Department of EEE, Nandha College of Technology, Erode, Tamil Nadu, India

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P. Marimuthu, Agalya V and J. Kumaresan

Abstract

Frequency control in interconnected power systems is essential for maintaining grid stability and ensuring reliable electricity supply. This paper investigates the application of Proportional-Derivative (PD) and Proportional-Integral-Derivative (PID) controllers for frequency control in a two-area interconnected power system. The study aims to evaluate the effectiveness of PD and PID controllers in regulating system frequency following disturbances or changes in demand. The research begins with an overview of frequency control challenges in interconnected power systems and the principles behind PD and PID control strategies. Analytical methods and optimization techniques for tuning controller parameters are discussed, highlighting the importance of selecting appropriate gains to achieve desired performance objectives. A detailed analysis of PD and PID controller performance in frequency control scenarios is presented, considering factors such as response time, overshoot, settling time, and stability margins. The study examines the robustness of PD and PID controllers under various operating conditions and explores potential limitations and areas for improvement.

Keywords: PID, PD, 2-area control

I. Introduction

In a two-area interconnected power system, each area typically consists of generators, loads, and transmission lines. The primary objective of frequency control is to balance generation and load in each area to maintain system frequency within acceptable limits following disturbances or changes in demand. PD controllers are characterized by their proportional and derivative terms, which provide control action proportional to the error (deviation from the desired frequency) and its rate of change, respectively. The proportional term ensures a response to the current error, while the derivative term anticipates future trends and helps damp out oscillations. PID controllers, on the other hand, incorporate an additional integral term, which integrates the error over time and helps eliminate steady-state errors. PID controllers offer improved performance compared to PD controllers by addressing both transient and steady-state response requirements.

Enhancing the stability of a power system during random load disturbances and minimizing power imbalances between generating resources and loads are critical tasks. Such efforts involve selecting and designing secondary controllers. These controllers play a pivotal role in maintaining system frequency close to its nominal value by addressing active power imbalances. Extensive literature discusses the importance of secondary controllers in Automatic Generation Control (AGC).

The widely used Proportional-Integral-Derivative (PID) controller finds frequent application in AGC for interconnected power systems. Additionally, researchers explore the use of Artificial Neural Networks (ANN) as intelligent controllers to address AGC challenges during load perturbations. Studies present intelligent ANN controllers applied to both two-area and extended six-area systems, leveraging neuro-fuzzy techniques for enhanced performance. Furthermore, a novel approach integrates fuzzy logic with PID control, utilizing Hybrid Particle Swarm Optimization and Differential Evolution (HPSODE) to achieve superior AGC outcomes compared to traditional methods. These intelligent controllers collectively represent a category of advanced control strategies aimed at optimizing power system performance under varying operational conditions.

In contrast, most AGC-related works are based on optimization techniques to tune optimal parameter gains of the controllers used in secondary control loops. Ant Colony Optimizer (ACO) is used for multi-area interconnected power system frequency control with different cost functions. In PSO utilized for PID tuning of a single area power system. In Ant Lion Optimizer (ALO) applied for secondary controller tuning for classical power system models and modern power system model with renewables, Whale Optimization Algorithm (WOA) is introduced to find optimal gains of the controllers at different loading and parameter uncertainties. Inline, Genetic Algorithm (GA), Differential Evolution (DE), Harris Hawk's Optimizer (HHO) and Bacteria Foraging (BF) optimization are also applied for identifying gains of the controller to minimize the frequency and tie-line power changes.

2. PD-ID controller for AGC application

During load perturbations, the frequency profile of the power system is improved using primary and secondary controls. Primary control depends on the regulation constant of the machine and the secondary controller is selective.

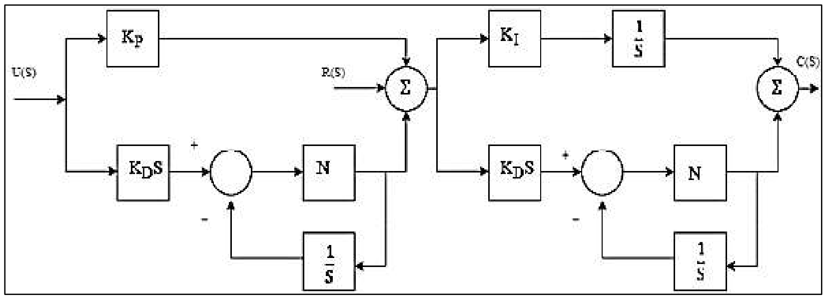

Fig 1: PD-ID controller block diagram

PID controller is used in earlier AGC-related articles. To improve the performance specifications of the power system during active power imbalances, other cascade controllers are alternative solutions to the PID controller. In this aspect, the PD-ID controller is considered in this chapter. The schematic diagram of the PD-ID controller is presented in Figure. 1.

In contrast to the PID controller, the PD-ID controller necessitates data on both the Area Control Error (ACE) and the change in frequency (Δ□). Its derivative components comprise filter elements with filter coefficients □1 and □2. As a result, the total tuning parameters for the AGC problem amount to 6 in single-area scenarios and 12 in situations involving two regions.

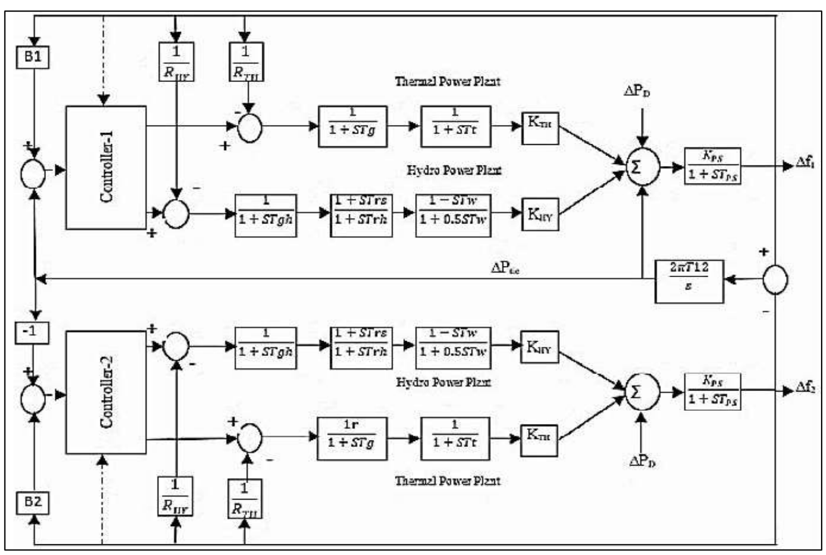

Fig 2: Two area interconnected system block diagram

3. Outline of invasive weed optimizer for AGC

The Invasive Weed Optimizer (IWO) is a metaheuristic optimization algorithm inspired by the behavior of invasive weeds in spreading, growing, and producing seeds. It has been adapted and applied to solve optimization problems, including those encountered in AGC systems. IWO operates based on the principles of natural selection and evolution, where candidate solutions evolve iteratively towards optimal or near-optimal solutions. In the context of AGC, IWO aims to find optimal parameter values for controllers to effectively regulate system frequency and maintain grid stability.

In Automatic Generation Control (AGC), the optimization of controller parameter gains is a critical task where metaheuristic optimization algorithms prove effective. This study employs an Invasive Weed Optimizer (IWO) to determine optimal values for the controller's gain parameters. The IWO algorithm draws inspiration from the spreading, growth, and seed production mechanisms of invasive weeds, initially proposed by Alireza Mehrabian and Caro Lucas (2006) for benchmark functions and subsequently extended to various engineering applications.

The IWO operates through three main phases: Initialization, reproduction, and spatial dispersal. During initialization, all solutions are dispersed randomly across the entire search space. In the reproduction phase, a select few plants generate seeds for the subsequent generation based on their functional values. Finally, in the spatial dispersal phase, seeds are dispersed with statistical parameters, featuring a mean value of zero and variable variance, positioned near the parent plant.

4. Simulation results

The study examines a two-area power system equipped with a PD-ID controller through four distinct case studies involving load variations on the demand side. In Case-1, a 10% load variation is introduced in area-1, and subsequent changes in frequency and tie-line power deviations are monitored and compared with those under a PID controller setup. Case-2 replicates this scenario but initiates the load change in area-2 instead.

In Case-3, random load perturbations are simulated to simulate load disturbances, while Case-4 explores the impact of noise and simple load changes. Tuning parameters for the area-1 controller across all case studies are detailed in Table. 1, while those for the area-2 controller are outlined in Table. 2. Through these analyses, the efficacy and advantages of the PD-ID controller over the PID controller are elucidated and discussed.

Table 1: Optimal parameter gains of PD-ID in area-1

Parameter	Casewise Description			
	I	II	III	VI
k_{p1}	-1.9992	-0.7671	-1.9994	-1.9772
k_{i1}	1.9990	0.0005	1.9944	1.9916
k_{d1}	-1.9887	-1.5590	-2	-1.9996
N_1	171.38	197.84	89.91	198.55
k_{d2}	0.6770	-0.4356	0.9530	0.7637
N_2	1.65	0.24	1.28	1.66

Table 2: Optimal parameter gains of PD-ID in area-2

Parameter	Casewise Description			
	I	II	III	VI
k_{p1}	-0.3799	-1.9861	-0.9666	-0.5644
k_{i1}	0.0022	1.9980	0.0032	0.0039
k_{d1}	-0.0997	-2	-1.9448	-1.6645
N_1	57.42	24.68	166.74	73.09
k_{d2}	-0.3969	0.7723	0.0024	-0.0522
N_2	8.36	1.55	173.23	106.13

In Case 1, the fluctuations in frequency for each area and the alterations in inter tie-line power are illustrated in Figures 3,4, and 5 respectively.

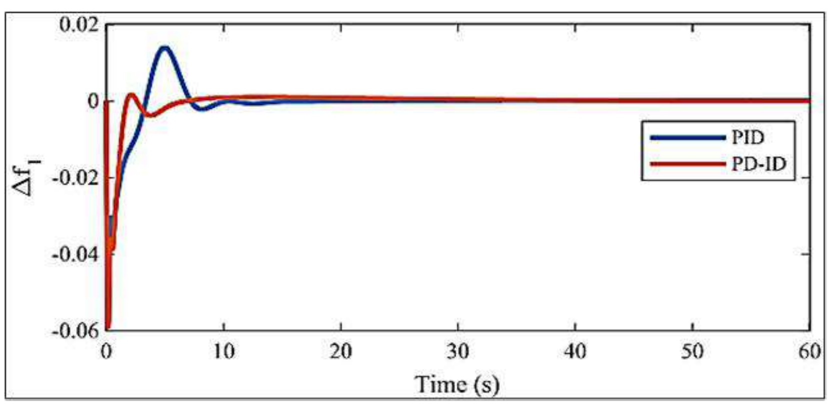

Fig 3: System change in frequency of area-1 for 10% load disturbance

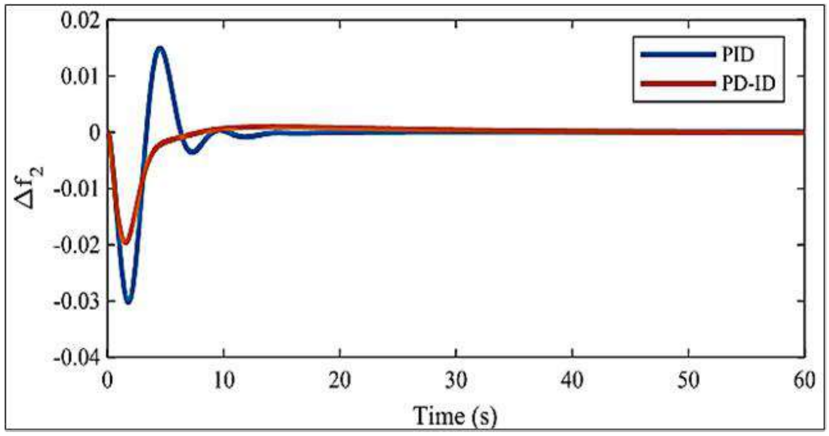

Fig 4: System change in frequency of area-2 for 10% load disturbance

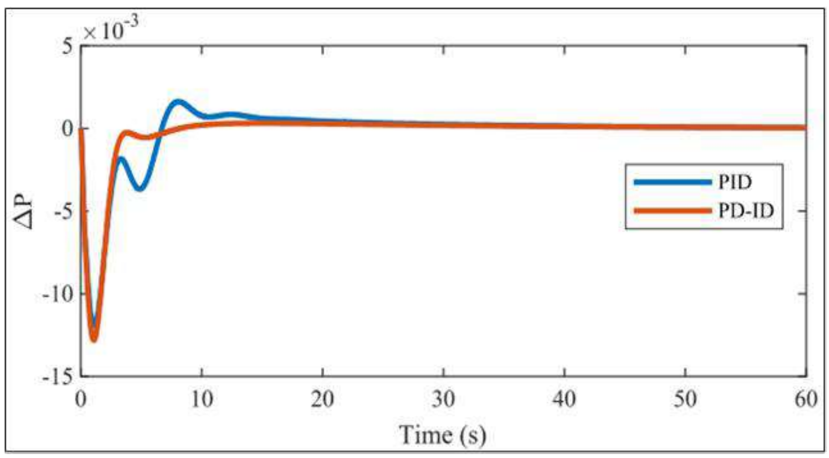

Fig 5: System change in tie-line power for 10% load disturbance

The findings indicate an improvement in the frequency profiles of each area upon replacing the secondary PID controller with the PD-ID controller. For comparison, the parameter gains of the IWO-tuned PID controller are considered. The optimal proportional, integral, and derivative gains for area-1 are -1.938, -1.938, and -1.982, respectively. Meanwhile, for area-2, the optimal gains for the PID block are 0.812, -0.037, and 0.255.

Conclusion

Upon reviewing the achieved outcomes, the proposed PD-ID controller exhibits superior performance. This controller, introduced within this study, targets the minimization of frequency deviations within interconnected power systems during load perturbations. It consistently surpasses the PID controller across diverse load change scenarios. The utilization of the IWO algorithm facilitates the swift acquisition of optimal parameter gains for the controllers. As a result, the proposed controller emerges as the prime option for ensuring frequency stability, as evidenced by the intricate case studies scrutinized in this research.

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