The Development of PID Controller by Chess Algorithm

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Abstract. *The paper discusses the design and analysis of the control of two interconnected thermal power generation systems using the proportional-integral-derivative (PID) control method, which is further enhanced by the Chess algorithm (CA). Typically, power and control systems exhibit non-linear behavior. Therefore, it is necessary to optimize the automatic gain controllers (AGCs), especially the PID controllers that rely on numerous factors. The Chess algorithms and Particle Swarm Optimization (PSO) have been introduced to enhance the parameterization and evaluate the effectiveness of this method in the context of a dynamic electric load size change approach. Through experimentation, employing the Chess algorithm to enhance the generating system's parameters will render the system more resilient to variations and yield superior performance.*

Keywords:

Automatic Generation Control, PID Control, Optimization Technique, Particle Swarm Optimization, Chess Algorithm

1. Introduction

The significance of designing and managing the power system lies in load frequency control as well as power management. More precisely, it refers to A power system characterized by the interconnection of multiple electrical power sources, where each source is required to operate at a uniform frequency. The primary objective of load frequency control in a power system is to maintain the stability of each generator's frequency and efficiently adjust the power distribution to meet the load requirements during both normal and dynamic situations.

Typically, an effective electrical control system design for a generator should possess the capability to manage variations in load and ensure high-quality voltage and frequency [1]. Simple electrical control systems have been extensively studied in the literature. We propose an optimal electrical system for consideration [2]. The utilization of control was initially implemented for the purpose of designing and regulating electrical systems in interconnected power networks. Optimizing power plant systems to achieve maximum efficiency and control over various applications. According to various mechanisms of regulation Methods for developing automated electrical system controllers the main objective is to enhance electrical automation controllers by implementing modern control techniques, similar to those found in nervous systems. The development of design and application involves various areas such as networks [3, 4], fuzzy system theory [5], reinforcement learning [6], ANFIS method [7, 8] and particle swarm optimization [9, 10] among others. Enhancing electrical efficiency. Controllers also advance from a rudimentary level to a more sophisticated Proportional-Integral-Derivative control system. For electrical systems exhibiting non-linear characteristics Nevertheless, the number is extremely limited. Optimization methods are utilized in the development of PID controllers, specifically for integrating systems in combined cycle power plants.

Heuristic optimization [11], along with the bee, ant, particle, and genetic methods, is used to solve non-linear problems by observing living organisms' behavior. The first algorithm, the genetic algorithm, could consistently find answers even when chromosomes were randomly distributed incorrectly and could avoid a specific result. Greater variability in chromosomes enhances the probability of discovering the most optimal solution or answer. However, genetics are complex, requiring more effort to find the best option. It cannot guarantee the best solution in a given timeframe. Because it uses the Boltzmann diffusion concept to lower source size and boundaries, The annealing simulation algorithm possesses the capability to solve any problem. The energy rerandomization in the annealing simulation algorithm is limited to adjacent ideal energy values, leading to the generation of a local solution.

Randomization is crucial. With a limited number of randomizations, the preliminary outcome took longer to determine the best response, especially when the initial response differed greatly from the best response. The initial randomization process involves generating responses that are significantly different from the optimal answer. Due to the limited number of random replies, this initial unpredictability poses a challenge in identifying the optimal answer. Without an optimal answer, a heuristic optimization method was developed to link an organism's real-time activity to its natural course by producing random beginning responses. There are infinite prototypes, like the Chess Algorithm Method, that can efficiently find solutions and prohibit specific answers.

This paper demonstrates the utilization of the Chess algorithm [12] to enhance the configuration of parameters of the PID controller in the interconnected power system of the combined cycle power generator. [13, 14], specifically in the presence of non-linear characteristics. This analysis assesses the power system's dynamic response by taking into account factors such as dynamic performance, integral of the squared error over time (ITSE), the integral of the time-weighted absolute error (ITAE) and sensitivity analysis of internal controls in abnormal conditions.

2. Mathematical Modeling for Two-area Interconnected Thermal Power Systems

This study evaluates the effectiveness of the Chess Algorithm in determining appropriate configuration parameters for the Proportional-Integral-Derivative (PID) controller in a thermal power system with two interconnected areas. During the simulation, each power plant possesses a production capacity of 2000 MW and supplies energy to a load of 1000 MW. A governor dead band was implemented in the system to enhance its realism. This modification rendered the system non-linear, enabling its application in analyzing the dynamic behavior of frequency in power plants, specifically the tie line power response to a Step Load Perturbation (SLP) disturbance of 0.01 p.u. in the thermal power plant located in area 1.
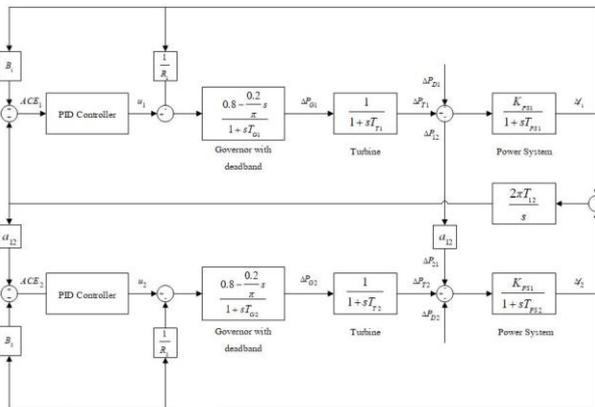

Fig. 1 Two-area Interconnected Thermal Power Systems

3. PID Controller

A PID controller [15] is a control mechanism designed to regulate the system's output to closely match the target value. The PID controller relies on three main components, namely proportional, integral, and derivative, to operate well. Collectively, these components modify and regulate the system's output in order to approximate the desired value. The PID controller is extensively employed in many systems that require precise control and attainment of desired values.
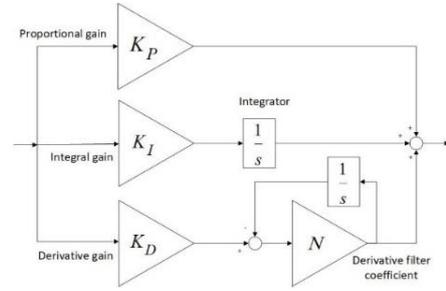

Fig. 2 PID Controller

3.1 Objective Function

The main objectives of system control in power systems typically include:

- The discrepancy in frequency across power systems should decrease to zero as the load fluctuates.
- The objective is to minimize the integral of the frequency error.
- The control system features must ensure the stability of the system.
- The power system in each source must be able to operate under both typical load conditions and when there are fluctuations in the load.

Based on the information provided, control objectives may be expressed as equations in the following manner:

$$ITAE = \int_0^\infty [|e(t)|^2] \cdot t \cdot dt \qquad (1)$$
$$ITSE = \int_0^\infty [e^2(t)] \cdot t \cdot dt \qquad (2)$$

Therefore, the performance indices represented by Equations 1 to 2 will be used as the objective function for the Chess Algorithm based PID tuning. In essence, the objective of Chess Algorithm based optimization in this scenario is to identify a precise combination of PID parameters that would lead to the feedback control system attaining the most minimal performance index. The objective function must be completed while adhering to the limitations imposed by the upper and lower limits of the parameters. The parallel PID controller, seen in Figure 2, consists of the following elements: proportional gain (Kp), integrator gain (Ki), derivative gain (Kd), and derivative filter coefficient (N), as explained by Equations 3 to 5 and Table1

$$K_{p\ min} \le K_p \le K_{p\ max} \qquad (3)$$

$$K_{i\ min} \le K_i \le K_{i\ max} \qquad (4)$$

$$K_{d\ min} \le K_d \le K_{d\ max} \qquad (5)$$

Table 1 Minimum and Maximum Value of The Control Parameter.

Controller Parameter	Minimum	Maximum
K_p	0	10
K_i	0	10
K_d	0	10

4. Chess Algorithm

The approach outlined in this study, known as Chess Algorithm Optimization Technique (CA), relies on the principles and strategies employed in the game of international chess to determine the optimal value. Furthermore, the user should consider the individual motions of each chess piece and the overall strategic approach to the game. If the aforementioned concept is employed to ascertain the optimal value, the player will achieve victory in the game. This will generate an algorithm with diverse characteristics in several domains. This concept leads to the development of an algorithm because, based on the game's style, each chess piece has the ability to move in certain ways according to a predefined set of rules. By using these concepts in optimization, algorithms that are very proficient in addressing a diverse array of complex problems will be created. The Chess algorithm comprises the subsequent steps:

Step 1: Randomize the solution by distributing 8 pawns (np). Responses must be feasible within constraints. Due to many mandatory requirements, the number of iterations must be one.

Step 2: Evaluate the random pawn assignments. By testing the function at each response. Ready to classify the response gives the function's worst value.

Step 3: Shows the sorted responses. Contains 1 king, 1 queen, 2 rooks, 2 knights, and 2 bishops in order.

Step 4: Assign items individually Based on the pieces' movements, find the solution nearby.

Step 5: Evaluate nearby responses. Evaluate the function for each response. find the best solutions nearby Each item

Step 6 reposition items. Find the best solution for component-environment compatibility.

Step 7: Compare search results with all chess pieces. What answer has the highest function value? Designate it the best solution in that search iteration.

Step 8: Check the conditions and add a local response. As long as the requirements are met. Let's free ourselves from limited solutions.

Step 9. Check termination criteria. If the criteria are met Search no more. Increase iterations if the requirements are not met. Add 1 to the current Iteration value to get the updated value.

Step 10: Distribute 8 pieces evenly and start over. In addition to determining the function value of the random pawn pick result,

Step 11: Combine the current optimal solution for all chess pieces (1 king, 1 queen, 2 rooks, 2 knights, and 2 bishops) with the initial pawn configuration (8 pieces). The 16 answers were ranked from best to worst.

Step 12 repeats step 3 with the top 8 responses until the stopping condition is met

5. Results and Discussion

Incorporating thermal power plants into the power system improves the overall resilience of the power grid. Command, particularly from a Proportional-Integral-Derivative (PID) controller, is crucial. This topic involves the presentation of controller architecture and objective functions.

The Chess algorithm adjusts the parameters of the PID controller, which regulates the power system's link between two sources. The MATLAB R2021a application is utilized to test and evaluate all operations. The application operates on a CPU with a Core i5 processor running at a clock speed of 2.50 GHz, and has 8.00 GB of RAM. The outcomes of optimizing the parameters of PID controllers using the Chess algorithm. are displayed in Table 2

Table 2 Optimization Controller Parameters.

Optimization technique/Controller parameters		ITAE	ITSE
Chess Algorithm	K_p	0.6451	0.7247
	K_i	2.2171	3.8523
	K_d	0.8435	1.2678
Particle swarm optimization	K_p	1.0828	1.3582
	K_i	3.0371	4.7225
	K_d	0.8706	1.2624

Table 2 displays the optimal configurations for PID. Regulator These settings are determined by a Chess algorithm. Hence, the goal is to minimize the integral of the squared error over time (ITSE) and the integral of the time-weighted absolute error (ITAE). Proportional Profit (K_p), Integrator Profit (K_i), and Derivatives are key factors at play in the context. The gain parameter (K_d) was determined to be similar to those values. Optimized using Particle Swarm Optimization (PSO)
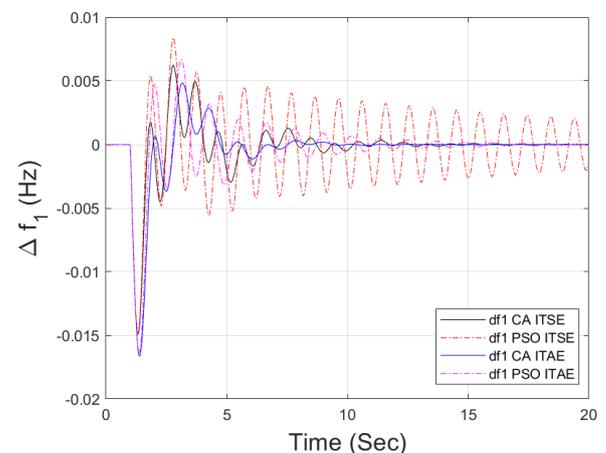

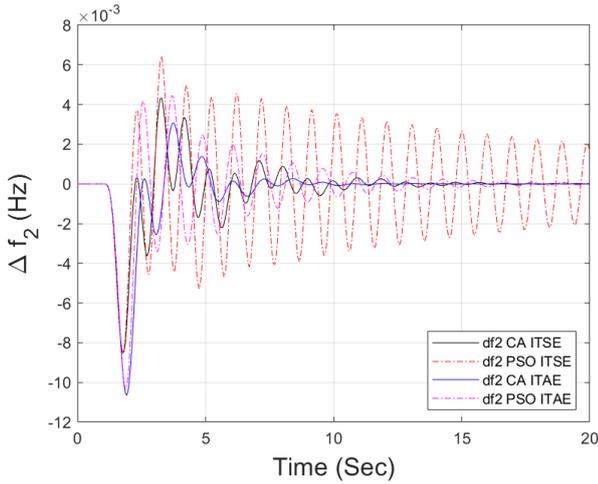**Fig. 3** The frequency variation of an area for a 1% change in area-1 can be measured using the ITSE and ITAE methods.

Fig. 4 The frequency variation of an area for a 1% change in area-2 can be measured using the ITSE and ITAE methods.
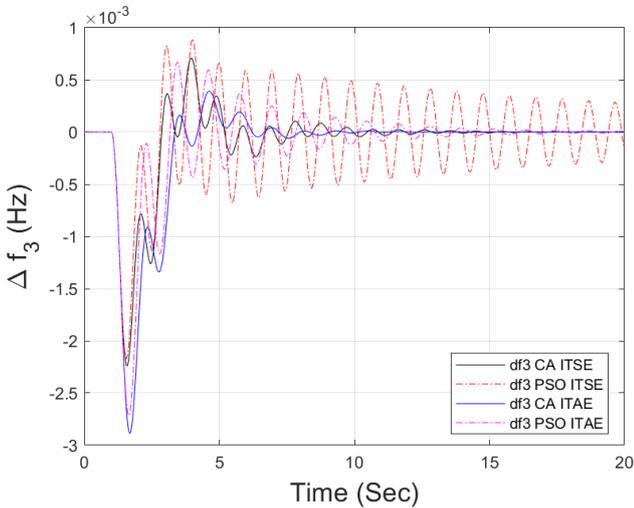

Fig. 5 The frequency variation of an area for a 1% change in area-3 can be measured using the ITSE and ITAE methods.

Fig. 3 and 4 illustrate the disparity in the frequency variation between generator systems 1 and 2 inside a control system for a two-source power connection. The PID controller's parameters were optimized using the Chess method and Particle Swarm Optimization is used to minimize the integral of the squared error over time (ITSE) and the integral of the time-weighted absolute error (ITAE). The conditional refers to a dynamic alteration caused by a 1% modification in the load connected to generating systems 1 and 2. It has been shown that the PID control with parametric adjustment of the Chess algorithm provides the most effective regulation of both the extent of overshooting and the progression towards a stable state. Fig. 5 illustrates the disparity in electrical power between two sources in the power system link. The study unveiled that the PID controller, The Chess algorithm, when parameterized, had a greater influence on power differentials and control compared to the Particle Swarm Optimization method.

Tables 4, 5 and 6 displays the proficiency of the controller in both Chess and Particle Swarm Optimization. The primary objective is to minimize the integral of the squared error over time (ITSE) and the integral of the time-weighted absolute error (ITAE). Table 4 displays this information. Performance metrics encompass peak undershoot, settling time, as well as errors $\Delta f1$, $\Delta f2$, and $\Delta f3$. Table 4 demonstrates that Chess algorithm controllers surpassed Particle Swarm Optimization controllers in every control domain. Managing complex power systems poses difficulties due to controller design issues. The PID controller has excellent performance. Design parameters for controlling chess algorithms. Complex power system management is necessary, which involves the utilization of a PID controller to govern both frequency and power. In this case, the objective is to minimize the integral of the squared error over time (ITSE) and integral of the time-weighted absolute error (ITAE), while considering the dynamic changes in the thermal power generating system that are influenced by two power sources. PID controllers are constructed and optimized via the Chess Algorithm. When compared to Particle Swarm Optimization controllers, it demonstrates exceptional mastery over all facets of intricate power systems.

Table 4 Displays the numerical values for Peak Overshoot

Optimization/ Controllers	Peak Overshoot (OS)		
	$\Delta f1$	$\Delta f2$	$\Delta f3$
CA (ITSE)	0.0149	0.0085	0.0022
PSO (ITSE)	0.0149	0.0086	0.0022
CA (ITAE)	0.0166	0.0107	0.0029
PSO (ITAE)	0.0164	0.0103	0.0027

Table 5 Displays the numerical values for Settling Time

Optimization/ Controllers	Settling Time (2% band) T_s(s)		
	$\Delta f1$	$\Delta f2$	$\Delta f3$
CA (ITSE)	208.4378	218.0509	189.1058
PSO (ITSE)	340.6580	340.8762	340.9350
CA (ITAE)	139.6686	161.2796	145.5203
PSO (ITAE)	227.9704	264.9829	223.5317

Table 6 Displays the numerical values for Error

Optimization/ Controllers	Error
CA (ITSE)	0.000300
PSO (ITSE)	0.002200
CA (ITAE)	0.000369
PSO (ITAE)	0.000490

Acknowledgments

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