Article

Load Frequency Control for Hybrid Power System by Modified PSO-PID Controller

Mahmood Hasan Alhafadhi [1,*], Mustafa Jamal Ahmed [2], and Husam Hamid Ibrahim [3]

[1] Institute of Physical Metallurgy, Metal Forming, and Nanotechnology, University of Miskolc, Hungary; femmahmood@uni-miskolc.hu
[2] Department of Biomedical Engineering, Institute of Applied Sciences, Faculty of Engineering, Near East University, Cyprus; 20227121@std.neu.edu.tr
[3] Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM), Selangor, Malaysia; p97884@siswa.ukm.edu.my
* Correspondence; Tel.: +60 172804671

Abstract: With a proportional integral derivative (PID) controller, the effectiveness of load frequency control (LFC) for separated a variety of electric power-generating devices is described. In the structure under study, a thermal and hydro power producing unit is combined. In order to maintain system efficiency in the event of an unexpected demand on the power structure, the PID controller is suggested as a secondary regulator. The suggested PID controller's optimum gain settings are found using the modified particle swarm optimization (MPSO) technique. The controller increase settings were optimized using a variety of expense processes, namely integral time absolute error (ITAE), integral absolute error (IAE), integral squared error (ISE), and integral time squared error (ITSE). Additionally, the efficiency evaluation of traditional PID controllers for a comparable system utilizing the differential evolution (DE) algorithm and genetic algorithm (GA) demonstrates the improvement of the MPSO approach. The findings demonstrate that in an electrical crisis, the MPSO-PID controller provides a quicker stabilized reaction and that the suggested technique's percent increase over the traditional way is over GA and over DE.

Keywords: proportional integral derivative (PID); modified particle swarm optimization (MPSO); Load Frequency Control (LFC)

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1. Introduction

Distribution of electricity and output, or the production and distribution of electricity based on user load demand, make up the electric energy system. Globalization and technological development have led to a daily increase in consumer appetite for power. By building new power plants and renovating old ones, the producing capacity is boosted to meet load demand. The power grid faces a number of problems when a complex power network is implemented, including voltage and frequency deviation [1].

The way that consumers utilize power is not linear. To guarantee stable system operation, power generation so changes proportionately with load demand. Rapid increases in power demand have an effect on the stability of the whole power-generating unit in a system or any linked system [2].

One of the most important factors affecting the grade of the energy strategy is frequency, and the LFC technique takes care of frequency fluctuation. A secondary controller should be involved into the strategy in order to implement the LFC scheme, which will increase performance and recover the specified power supply [3]. Because the secondary controllers aren't able to achieve the required outcome, the controller gain has to be improved. The literature research in this study included a variety of optimal methodologies to enhance the controller gain parameters. The reaction of secondary controllers and optimization techniques that have been tried and tested are covered in the sections that following [4].

The literature that is relevant to the proposed work is included in the description, like deferential evaluation algorithm [5, 6], novel optimized fuzzy logic control [7], optimal fractional-order fuzzy PID controller [8], moth flame optimization algorithm [9], hybrid bacteria foraging optimization algorithm [10] fitness dependent optimizer [11], fractional order [12] particle swarm optimization [13] and it demonstrates how many experts adjust the controller gain settings using the MPSO optimization approach. Furthermore, a backup PID controller was built for the suggested power supply. To demonstrate the MPSO's superiority, comparisons with other widely used techniques, including the conventional, GA, and DE algorithms, were made.

The primary benefit of MPSO is its ability to provide high-quality solutions while avoiding premature convergence to local minima. The primary benefit of MPSO is that it has fewer tuning parameters. By using a high-dimensional search space and particle interactions, MPSO finds the optimal solution.

In this study, the MPSO–PID controller was used with various expense processes. The system's effectiveness was assessed by comparing its response to a PID controller for an identical power system that had been modified using a conventional, genetic, and differential evolution method. This study's key objectives were to improve the suggested system's performance and preserve system stability in urgent circumstances so that all customers could get high-quality electricity. In order to overcome the crisis, a PID controller that was adjusted using MPSO and four distinct expense processes was used to enhance the system parameters. Using the same criteria, the MPSO-PID response was also evaluated in comparison to traditional, GA, and DE-based PID controller comebacks.

In this research, expected traditional generation sources were combined with an isolated power system. Only one expense processes were considered in the design and exploration of the present work. By examining the effectiveness of the suggested controller and optimization strategy in the addressed power system with four different expense processes, this research, in contrast, narrows this disparity. A thorough analysis was done to ascertain the exact advantages of the recommended upgraded controller.

2. Materials and Methods

2.1 Computational Simulation of the Power System

Three different types of power-generating units—thermal and hydro units—are included in the planned power network. In addition, a PID controller has been added to control the fluctuation and all three units were seen as the source of a single system. Figure 1 displays the Simulink model of the suggested system configuration. The suggested system's mathematical formulation is as follows, as covered in [5, 14]:

Components of the thermal power system:

$$\text{Governor} = \frac{1}{1 + sTsg} \tag{1}$$

$$\text{Reheater} = \frac{1 + sKr \times Tr}{1 + sTr} \tag{2}$$

$$\text{Steam turbine} = \frac{1}{1+sTt} \tag{3}$$

Components of the hydropower system:

$$\text{Governor} = \frac{1}{sTgh + 1} \tag{4}$$

$$\text{Drop compensation} = \frac{Tr + 1}{Trhs + 1} \tag{5}$$

$$\text{Penstock turbine} = \frac{-Tws + 1}{0.5Tws + 1} \tag{6}$$

where Tsg, Tr, and Tt stand for the duration characteristics of the steam generator, the reheater, and the regulator, correspondingly. The duration characteristics for the governor, drop reimbursement, penstock turbine, and hydro power station are Tgh, Tr, Trh, and Tw, in that order. Employing the MATLAB/Simulink framework for frequency control, a Simulink model was created for analysis based on the transfer functions of the intended energy system. A step load perturbation (SLP) of 0.99% was applied throughout the research.

Using the MATLAB/Simulink software to simulate frequency control, a Simulink model was created for analysis based on the transfer functions of the planned energy system [5, 14].

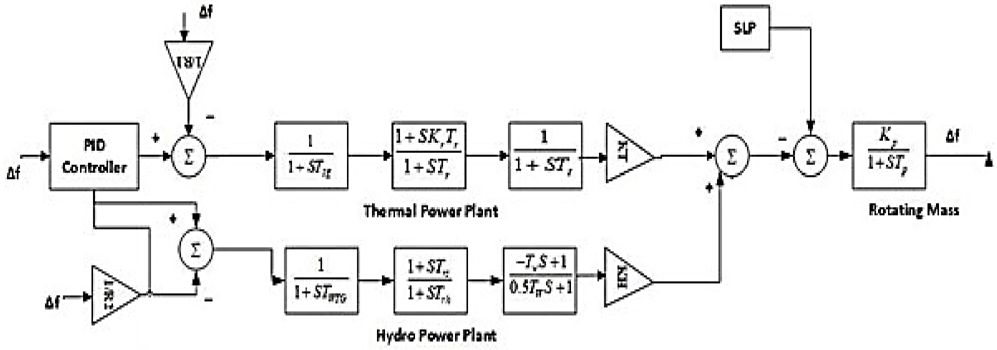

Figure 1 shows the suggested system's mathematical framework.

2.2 Method of Regulation

In the realm of technology and control, the PID controller is a widely used device. The PID controller is minimal to develop, install, and operate. It is capable of self-adjusting to the chosen value. As per references [15, 16], the PID controller's mathematical equation is:

$$G(s) = Kp + \frac{Ki}{s} + sKd \qquad (7)$$

where the increases of the proportional, integral, and derivative controllers are, respectively, Kp, Ki, and Kd.

$$JIAE = \int |ACE| dt \qquad (8)$$

$$JITAE = \int t.|ACE| dt \qquad (9)$$

$$JISE = \int \{ACE\}^2 dt \qquad (10)$$

$$JITSE = \int t.\{ACE\}^2 dt \qquad (11)$$

2.3 Traditional Technique of Tuning

The traditional technique of test and error-tuning was employed to get the ideal controller increase ratio. In this tuning manipulate, the initial integral increase rate (KI) has been adjusted by trial and error. The ideal benefit value for KI was established as an ongoing amount when it was discovered. After that, similar to the integral increase value, the proportional increase rate (KP) has been adjusted to reach its ideal value. Then, as recommended by [15, 16], the derivative controller increase rate (KD) was modified after the KI and KP were set as constants. The curves corresponding to the effectiveness markers for the IAE, ISE, ITAE, and ITSE.

Applying the many price functions that were researched, the ideal rate of the PID controller increase were determined at the conclusion of the adjusting procedure and are displayed in Table 1.

2.4 Modified Particle Swarm Optimization Tuning Method

A better MPSO method for the issue of hydrothermal scheduling

The following phases may be used to characterize the computational operations of the MPSO technique:

• Stage 1: Enter the system's parameters and designate the upper and lower bounds for each variable.

• Stage 2: Only the number of population particles and the initializer.

• Stege 3: Assign the trial vector Qp = [q11, q12, ..., q1m; q21, q22, ..., q2m ,...,qn1, qn2, ..., qnm] to represent the population particles that need to develop. The reservoir turbine outflows at different periods, according to their capacity limitations, are the components of qij. Among the committed m intervals, qid, which depends on output of ith hydroelectric plant at dth interval, is chosen at randomness. Next, the storage contents of reservoirs Vij are computed given the hydro discharges. Next, PHij is computed using.

• Stage 4: Compare the assessment score for every single particle (24 - 4) with its Pbest. Between Pbest, the best assessment score is shown by gbest.

• Stage 5: Restart the loop with k = k+1; modify the location, velocity, and weight of gravity.

• Stage 6: Only after all restrictions are met is each particle's revised position assessed. if each particle's assessment value outperforms the prior Pbest. Pbest is the value that is currently set. The value is set to gbest if the best Pbest outperforms gbest.

• Stage 7: Using equations (12) and (13), the dynamic search-space squeezing approach is triggered to modify the top and lower limits of the particles in relation to the most recent gbest.

• Stage 8: Display the outcome and end if the halting requirement is met; if not, continue with Stages 2.

$$q_{ij,min}^{k+1} = q_{ij,min} + \left(gbest_p^k - q_{ij,min}\right) \times \Delta_{L,ij}^k \qquad (12)$$

$$q_{ij,max}^{k+1} = q_{ij,max} + \left(q_{ij,max} - gbest_p^k\right) \times \Delta_{L,ij}^k \qquad (13)$$

Following the tuning stage, the PID controller's proper boost constants were established in order to preserve power system stability in the face of unanticipated load variations or emergency case configurations [17]. The increase values derived via MPSO tweaking are shown in Table 2.

Table 1. shows the traditional PID controller's boost settings.

Optimized Increase	K_p	K_i	K_d
IAE	0.99	0.39	0.01
ISE	1.19	0.39	0.12
ITAE	0.59	0.35	0.99
ITSE	0.99	0.39	0.29

Table 2. Increases rates of the MPSO to optimal PID controller parameters

Optimized Increase	K_p	K_i	K_d
IAE	1.00	1.00	0.11
ISE	1.00	1.00	0.14
ITAE	0.81	1.00	0.19
ITSE	0.98	1.00	0.09

3. Model Outcome

The suggested system's simulator was created using MATLAB 2016a. The traditional, GA, DE, and MPSO–PID controller answers are examined in this section for their respective capabilities. The system's efficiency was assessed for several optimization methods employing 0.99% SLP. In the end, the MPSO performance has been evaluated by contrasting it with a PID controller's performance that was tuned using a traditional, GA, and DE method. It demonstrates the frequency reaction is compared with different expense processes. The traditional, GA, DE, and MPSO-tuned PID controller replies correspondingly. Table 3 provides the equivalent regulated statistical rates to the frequency deviation (delF), where Ts stands for settling duration, POS for maximum overshoot, and PUS for maximum undershoot.

Table 3. Manipulated factors of delF using the ISE expense processes

Methods	Ts (S)	POS (Hz) $\times 10^{-3}$	PUS (Hz) $\times 10{-}3$
Traditional	90	0.3	6.7
GA	47	0.2	6.6
DE	53	0.3	6.6
MPSO	42	0.3	6.8

Table 4. Manipulated factors of delF using the IAE expense processes

Methods	Ts (S)	POS (Hz) $\times 10^{-3}$	PUS (Hz) $\times 10{-}3$
Traditional	59	0.2	11.3
GA	49	0.1	10.6
DE	43	0.1	10.6
MPSO	37	0.1	6.9

Analysis was done on the frequency deviation's reaction for various expense processes. The MPSO–PID controller with the ISE price function produced superior outcomes than the other methods, according to the thorough investigation. Compared to the others, the MPSO–PID with ISE calmed the oscillation faster, at 44.9 s. The suggested controller outperformed the traditional model by 98%, the GA by 6.9%, and the DE by 19.9%. It illustrates the delF evaluation for the IAE expense processes, and Table 4 reports the mathematical outcomes.

The MPSO–PID controller outperforms the other optimization methods based on the graphical and mathematical responses evaluation of the suggested controller with the IAE expense processes in Table 4. For 39 seconds, it managed the oscillation. The MPSO–PID controller outperformed the traditional regulator by 44.9%, the GA controller by 24%, and the DE controller by 4.8%, measured in percentages. The delF contrast for the ITSE expense processes are shown in Table 5 gives the numerical data.

Table 5. Manipulated factors of delF using the ITSE expense processes

Methods	Ts (S)	POS (Hz) $\times 10^{-3}$	PUS (Hz) $\times 10{-}3$
Traditional	59	0.2	10.3
GA	46	0.1	8.5
DE	43	0.1	7.6
MPSO	37	0.1	7.3

Table 6. Manipulated factors of delF using the ITAE expense processes

Methods	Ts (S)	POS (Hz) $\times 10^{-3}$	PUS (Hz) $\times 10{-}3$
Traditional	60	0.2	13.9
GA	52	0.1	9.4
DE	42	0.05	10.7
MPSO	31	0.04	6.4

Table 6 provide a frequency response comparison based on the ISTE expense processes, which indicates that the MPSO–PID controller outperforms the other optimization strategies. The oscillation was stabilized at 40 s using the MPSO-PID controller. The MPSO–PID controller outperformed the traditional approach by 50%, GA by 14%, and DE by 7.7%. Table 6 provide the graphical and numerical comparison of del F for the ITAE expense processes, respectively.

In Table 6, the MPSO–PID controller's efficiency is compared with several optimization methods; it outperforms the traditional, GA, and DE algorithms. The oscillation was stopped after 32.8 seconds using the ITAE-based MPSO–PID controller. The MPSO–PID controller outperformed the traditional technique by 78%, GA by 54%, and DE by 23% in terms of percentile gain. Figure 2 shows a comparison of the four expense processes for settling time in a bar chart.

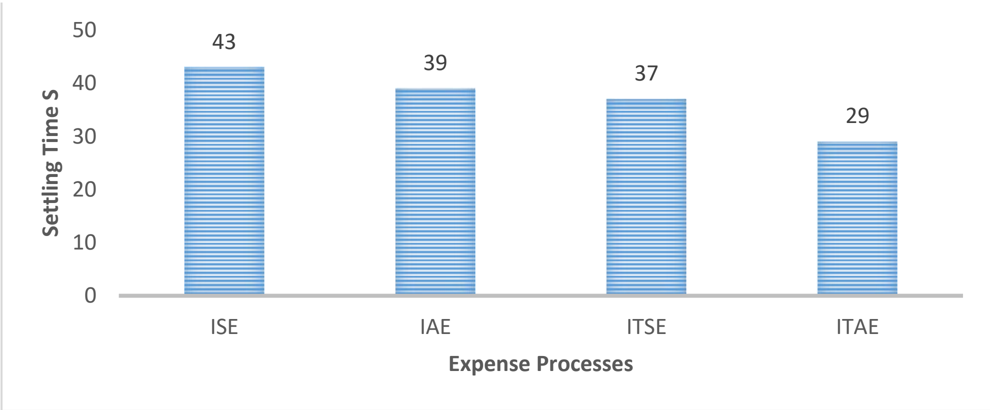

Figure 2. An examination of the MPSO–PID controller's settling time

Finally, a bar chart in Figure 2 contrasted the MPSO–PID controller comeback with each of the four expense processes. It demonstrates that the rapid settled comeback over other expense processes (IAE, ISE, and ITSE) indicates that the ITAE expense processes -based PSO–PID controller offers a superior reaction than other expense processes.

4. Conclusions

This paper provides a comprehensive performance analysis of the LFC for a single-area, multi-source power-generating system equipped with a supplementary PID controller. The MPSO approach with four different expense processes, along with conventional tuning, GA, and DE methods, were used to calculate the gain settings for PID controllers. The analysis of the system performance evaluations showed that the traditional, GA, or DE algorithm-tuned controller performance is not as well-regulated as the MPSO–PID controller with an ITAE expense processes-based controller. In a similar vein, comparisons were made between the MPSO–PID controller's responsiveness with other expense processes. In comparison to other expense processes and improvement method controller responses, the PSO–PID controller with the ITAE expense processes has been more prevalent.

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