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Automatic Temperature Control System Using African vultures optimization algorithm

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ABSTRACT One of the most important tasks in control engineering is tuning a PID controller for maximum efficiency. However, without a great deal of practice, manual adjustment of PID settings might result in erroneous results. Using met heuristic algorithms is one method for tweaking the PID controller. These algorithms, which are inspired by the laws of nature, can effectively find the sweet spot for the PID settings. Therefore, instead of manually tweaking the PID controller, using met heuristic methods can greatly enhance the system's performance while decreasing the related expenses. A reliable temperature control system is crucial to the production of a wide variety of industrial goods. The fact that it uses less energy than rivals makes it a hot commodity. The console is the most effective way to monitor this procedure. The air conditioning in the room is managed by a whole new model built on metaheuristic algorithms. The temperature regulation is processed using a PID controller based on the AVOA algorithm. Overshot, settling, and rising times have all been shortened. along with other methods from the literature, such the Ziegler-Nichols and PSO Optimizer algorithm. Efficiency was evaluated in terms of percent overrun, reaction time, settling time, and steady state error. Integral Time Squared Error (ITSE), Integral Time Absolute Error (ITAE), Integral Absolute Error (IAE), and Integral Squared Error (ISE) are used to compare the empirical data.

1. INTRODUCTION

It is common knowledge that traditional proportional integral derivative (PID)-type controllers are the most used in industry because of their straightforward control structure, simple design, and low price. To the contrary, if the controlled object is very nonlinear and unpredictable, the PID type controller will not produce satisfactory control performance [1]. Particle swarm optimization and evolutionary algorithms are two examples of intelligent approaches proposed to improve PID tuning beyond the limits of traditional PID parameter tuning methods. Recent advances in computational approaches have led to an increase in the presentation of optimization strategies for adjusting the system's governing parameters for peak efficiency [2]. K s = KP + Ki s + Kd s is the transfer function of the PID controller. Where Kp, Ki, and kd represent the proportional, integral, and differential gains. The proportional portion of a PID controller mitigates the dynamic response and increases system stability, while the integral portion eliminates the steady-state error and the derivative portion dampens the error responses to disturbances [3]. In general, the error signal is expressed as,

$$e(t) = u(t) - y(t) \tag{1}$$

The literature frequently employs the error signal provided by Eq. (1) for the aforementioned four performance metrics. IAE, ITAE, ISE, and ITSE are the criteria, and their respective formulae are as follows [9]:

$$ISE = \int_0^\infty e(t)^2 \, dt \tag{2}$$

$$IAE = \int_0^\infty |e(t)| \, dt \tag{3}$$

$$ITSE = \int_0^\infty t \times e(t)^2 \, dt \tag{4}$$

$$ITAE = \int_0^\infty t \times |e(t)| \, dt \tag{5}$$

Keeping a room's temperature at just the right level is one of PID control's most useful uses. Certain systems of control must be used in order to fulfill this application. The PID controller's ability to successfully manage the temperature through continuous output adjustment in response to real-time measurement is a function of how well you tune its three components [6]. To attain and maintain the intended temperature set point, the controller computes a suitable control signal, which is then utilized to regulate heating or cooling components. In this research, we offer an AOVA algorithm-based technique for determining the best PID controller settings.

2. Related Work

In 2019, YUANPING SU, QIUMING YU, AND LU ZENG, An STPID (self-tuning PID control) method is proposed here. The indoor temperature, humidity, and carbon monoxide concentration are among the three environmental outputs translated into the four equivalent unit outputs that are then regulated by four PID controllers. This means that the original system may be separated into its constituent PID controllers and their comparable outputs [7].

In 2020, Ting-Yun Wu 1 , Yun-Zhi Jiang 2,* , Yi-Zhu Su 3 and Wei-Chang Yeh 3, the purpose of this work is to propose the flow and temperature controllers of a cockpit environment control system (ECS) by employing an optimum simplified swarm optimization (SSO) fuzzy proportional-integral-derivative (PID) control [8].

In 2021, shika Sharma and Monika Singh, proposed The goal of this study is to develop an infant warmer that is outfitted with digital scales, with temperature settings of 350C, 360C, and 370C using PID control to stabilize the temperature and ensure the spread of heat on the bed evenly.

Then, the addition of skin temperature aims to make it possible for nurses to know what the patient's body temperature is when observations are being made. This research was carried out in order to address a need in the healthcare industry [9].

In 2021, Ketut Agung Enriko, Ryan Anugrah Putra, EstanantoThis study's objective is to design a model of a chicken coop that employs the proportional integral derivative (PID) control strategy as its primary method for regulating temperatures on intelligent poultry farms. It is anticipated that the PID control approach will make it possible for the temperature management system to adjust to the temperature that is present within the cage, which will aid chicken farmers in their work [10].

In 2021, Changhao Piao, Weiwei Wang, Ziyang Liu, Cunxue Wu, and Rongdi Yuan, In this work, fuzzy rules are designed, and fuzzy PID is utilized, in order to achieve temperature regulation in the passenger compartment. In comparison to PID control, fuzzy PID control has an overrun that is 1.6% lower and a setup time that is 39 seconds shorter. At the same time, this research develops a model of thermal comfort based on the temperature and humidity within the cabin [11].

In 2022, Igor Kocić, Saša S. Nikolić, Aleksandra Milovanović, Darko Mitić, Petar Đekić and Nikola Danković, In this study, the control software for the temperature management of the extruder zones with the mutual impact of zones is created, and it is detailed [12].

In 2022, yuan hao bin, wang yan, In order to achieve the function of automated and correct adjustment of indoor temperature, the primary emphasis of this article is study and design of the positive importance of iterative algorithm in PID control to the temperature control system model [13].

3. Fundamentals of PID Controller

A typical form of feedback controller that is utilized in control engineering is known as the proportional-integral-derivative controller (PID controller). This is due to the fact that its important role in the industrial control system is founded on the construction of a feedback control loop that is adaptable [14].

P, I, and D are the three fundamental terms that are used in the classic PID controller. PID is an abbreviation that stands for "Proportional, Integral, and Derivative." There are three distinct types of gains that may be distinguished from one another: proportional gain, integral gain, and derivative gain. In proportional gain, the relative relevance of the present error is taken into consideration, whereas in integral gain, the cumulative history of the error is considered instead. Adjustments to the control system are based on an aggregate that is weighted according to the occurrence of these three events [15].

The output of a PID controller is reduced by a constant error in order to achieve the target value, which is the same as the measured value. The internal workings of a typical PID controller are illustrated in Figure 1, and the equations (6) and (7) that follow describe how the output of the controller may be determined. There is a

$$u(t) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{de(t)}{dt} \tag{6}$$

and,

$$G_s(s)\frac{U(s)}{E(s)} = K_P + \frac{K_I}{s} + K_D s \tag{7}$$

where $u(t)$ is the output of the PID controller, K_P represents the proportional gain, K_I represents the integral gain, and K_D represents the derivative gain. The symbol e(t) is used to indicate the mistake in the calculation. The development of fractional calculus by podlubny and colleagues, on the other hand, has very recently paved the way for a shift away from classical models and toward ones that are characterized by non-integer order differential equations [16].

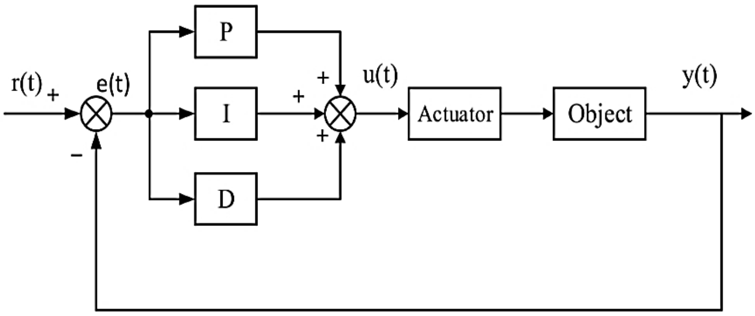

FIGURE 1. Diagram of a PID controller.

3.1 Proportional Control (P)

The output of a proportional controller is utilized in the process of error correction for various aspects of the system. Regrettably, doing so results in an offset error being generated by the system. Realize that lowering the inaccuracy of the permanent regime is the result of raising the action of a proportional factor, and that this impact has the consequence of increasing the action of the proportional factor. In contrast, when this process is amplified, the system is more likely to display more oscillations in the process variable. This is because there will be more of a feedback loop between the two processes[16].

3.2 P-I Controller

The primary purpose of P-I control is to eliminate the steady-state error introduced by the P regulator. On the other hand, it has detrimental consequences on both the response time and the overall stability of the system. This control is preferred where there is not a concern regarding the pace of the scheme. P-I control is unable to reduce the amount of time required for the rising time or eliminate oscillations because it lacks the ability to anticipate faults in the prospect system. Any value you choose to assign to I will result in an overshoot of the set point[15] .

3.3 P-D Controller

Increasing system stability and, as a result, control quality may be accomplished through the utilization of the P-D controller, which has the potential to anticipate future faults in scheme response. The output response of the scheme is used as the starting point for the production of derivatives, which are then used to lessen the effect of a sudden change in the value of the error signal. Since sudden shifts in the accuracy signal might result in unexpected shifts in the control output, it is commonly believed that the D system is proportional to variation in the output variable. This is because sudden shifts in the accuracy signal could create unexpected shifts in the control output. In addition to this, D openly enhances processing noise, which renders the D-alone strategy impossible to implement [17].

4. African vultures optimization algorithm

In this part of the article, the AVOA metaheuristic algorithm is described, along with the biological laws that govern vultures' lives. This subsection's objective is to provide a brand-new metaheuristic algorithm known as AVOA, which is derived from the robust ideas and notions that have been discussed. The AVOA algorithm is implemented after the simulation and formulation stages of every metaheuristic algorithm development, after which a set of assumptions regarding the natural world are taken into consideration. In this part, the AVOA algorithm will be implemented in a step-by-step fashion, and each step of the proposed algorithm will have all of the relevant circumstances and points explained in accordance with the fundamental ideas that have been presented regarding vultures. Following the formation of the initial population, the fitness of all solutions is computed, and the best solution is chosen as the best vulture of the first group, and the second-best solution is chosen as the best vulture of the second group; the other solutions using Eq. (8) then converge on the best solutions for the first and second groups. The entire population is reassessed for fitness at each cycle [18-20].

$$R(i) = \begin{cases} BestVulture1 \ if \ p_i = L_1 \\ BestVulture2 \ if \ p_i = L_2 \end{cases} \tag{8}$$

In Eq. (8), the likelihood of picking the chosen vultures to steer the other vultures toward one of the optimal solutions in each group, where L1 and L2 are two sets of vultures. Both of the search operation's input parameters must have values between 0 and 1, with the total being 1.

To select any of the strategies in the randP1exploration phase, a random number between 0 and 1 generate is generated. If this number is greater than or equal to the P1 parameter, Eq. (6) is used.

$$P(i+1) = R(i) - D(i) * F \tag{9}$$

The random motion is amplified by employing a coefficient vector X, which is calculated using the formula X = 2 rand, where rand is a random number between 0 and 1. The vulture's current vector position, P(i), is denoted by the symbol.

$$P(i+1) = R(i) - F + rand_2 * ((ub - lb) * rand_3 + lb \tag{10}$$

In Eq. (8), R(i) is one of the best vultures selected by the use of Eq. (1) in the current iteration. On the other hand, sick or injured vultures will congregate around healthy vultures in an effort to wear them out and steal food. This process is modeled using Equations (11) and (12).

$$P(i+1) = D(i) * (F + rand_4) - d(t) \tag{11}$$

$$d(t) = R(i) - P(i) \tag{12}$$

The random coefficient is multiplied by rand4, which is a random number between 0 and 1. Eq. (11) takes as input the current vector location of the vulture, P(i), and as output the distance between the vulture and one of the best vultures in the two groups, R(i), chosen using Eq. (8). In this strategy, we develop a spiraling equation involving all vultures and one of the top two vultures. Eqs. (13) and (14) describe the circular flight.

$$S_1 = R(i) * \left(\frac{rand_5 + P(i)}{2\pi}\right) * \cos(P(i))$$

$$S_2 = R(i) * \left(\frac{rand_6 + P(i)}{2\pi}\right) * \sin(P(i)) \tag{13}$$

$$P(i+1) = R(i) - (S_1 - S_2) \tag{14}$$

Using Eq. (8), we can determine which of the two best vultures is located at position i, and hence R(i) in Eqs. (13) and (14). The functions of sine and cosine are shown by the symbols cos and sin. And,rand5 and rand6 are arbitrary numbers between zero and one. If we utilize Eq. (13), we can determine S1 and S2. Finally, the vultures' locations are revised using Eq. (14).

$$P(i+1) = \frac{A_1 + A_2}{2} \tag{15}$$

In the end, Equation (16) is used to collect all of the vultures into a single flock. However, not all vultures are peaceful when they're hungry. They're heading in opposite ways to meet up with the head vulture. This motion may be modeled with Eq. (16).

$$P(i+1) = R(i) \left| d(t) * F * Levy(d) \right. \tag{16}$$

In Equation (16), the value of d(t) indicates the distance between the vulture in question and one of the more successful vultures from either of the two groups. In order to improve the performance of the AVOA in Equation (16), the usage of Levy flight (LF) patterns has been used.

The default AVOA is presented as follows. It is possible that a habitat has as many as N vultures. The same number of population is determined in both the heuristic and metaheuristic algorithms, but the number itself is determined by the problem that the researchers wish to solve using the AVOA.In a natural setting, a large number of vultures may be physically separated into two categories. In order to do this, the algorithm must first compute the fitness function of the entire population (the original population) before separating the vultures. The first solution is presented as the second-best vulture, while the best answer is referred to as the first and best vulture. Others come together to create a colony that, during each performance, either moves or replaces one of the two best vultures.

This algorithm separates the groups because it is possible to construct the most important aspect of vultures' natural behavior, which is to live in groups in order to search for food. The inability to locate and consume food is shared by all of the vultures, despite their similar appearance .

They are able to get free of the hungry trap because vultures have a voracious appetite and will search for food for long periods of time. When it comes to the formulation stage of our anti-hunger compromises, the vultures strive to keep their distance from the worst and come up with the best solution while operating on the assumption that the weakest and most hungry members of the population represent the worst answer. In the AVOA, the two best solutions are compared to each other to determine who is the strongest and best vulture. The other vultures do their best to get closer to the greatest .

Algorithm 1: General AVOA Algorithm Steps

1 **Start**
2 **Initialise the population:** Utilizing random generation, compile a list of probable solutions to the problem, and submit them for consideration.
3 **Evaluate the population:** Determine each solution's relative merit within the population by computing its fitness.
4 **Select the best solutions:** Determine which members of the population offer the most viable solutions and pick them.
5 **Generate new solutions:** Create new solutions by fusing together the most successful aspects of existing ones from the previous stage.
6 **Evaluate the new solutions:** Determine whether or not the new solutions are viable options.
7 **Select the best solutions:** Choose the most viable options from the population by evaluating their level of physical preparedness.
8 It is necessary to continue doing Steps 5–7 until a termination condition is satisfied.
9 **End**

5. The Proposed adaptive Temperature System

In order to zero in on the optimal settings for the Temperature Transfer Function value regulating variables, the proposed system makes use of a controller of the PID_ AVOA type. Figure 3 illustrates the PID control block layout that yields the best results for a temperature transfer function. The AVOA approach that has been developed uses subatomic particles I, P, and D to construct each individual particle. Because of this criterion, it is required that there be a three-dimensional search space, and it is also necessary that the population 'walks' in this space. Figure (4) presents a signal flow diagram for a PID_ AVOA controller. This diagram may be found in the previous figure.

Modeling the process of choosing PID parameters as a search space issue that has to be solved is done. As a result, metaheuristic algorithms may be utilized to identify strongly related parameter vectors and fine-tune the search space. The following are some examples of situations in which the method that was proposed was used to fine-tune the PID settings. Given that the values of the control unit were selected at random from within a particular range between zero and ten, the values that fall within this range are worked on repeatedly until the requisite values that make the Temperature current stable are attained.

PID_ AVOA is used to determine the rating value of the temperature and the current in order to accomplish the desired result of a quicker Temperature than the initial value of the temperature. The cost function for the optimization technique is chosen in accordance with the objective, which can either be to maximize the domain constraints or to lower the preference constraints. The new temperature needs to be at the points that have been indicated in order for us to be able to rely as much as possible on reliable readings. As a result, the margin of error must be as minimal as is practically feasible, and the temperature of the system must not experience any changes once it has been brought up to the appropriate level.

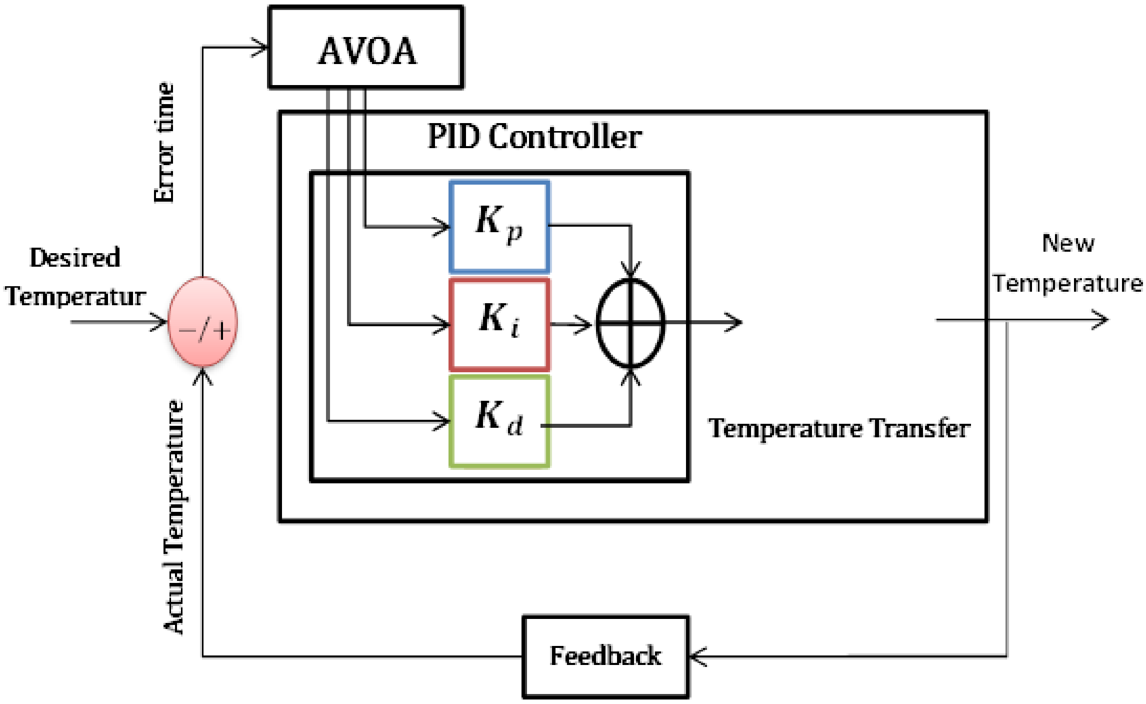

FIGURE 2. A PID controller for a Temperature block diagram.

The Temperature Transfer Function is the system that has to be controlled, as the block diagram clearly demonstrates. The purpose of any control system is to figure out how to create the associated actuation (intended Temperature; New Temperature) in order to obtain the controlled variable that is desired as the output of the system.

The feedback control has to do a comparison between the actual Temperature and the goal Temperature at which the system is working in order to guarantee that the value of the Temperature remains consistent. It is the responsibility of the controller to take into account the error term and convert it into instructions for the actuators in such a way that the error may be brought closer and closer to zero over time. By utilizing the AOVA method, the PID controller demonstrates how we may gradually reduce the error until it reaches zero.

6. Result and Discussion

When utilizing AOVA, you can acquire the best possible values for PID. This is because AOVA treats all of the available control parameter values as particles that may be utilized to minimize the goal or cost function. The values that show in the results of the control units are the ones that are considered to be possible values. In this example, such values are overshoot, rising time, settling time, and steady-state error. For the purpose of the current investigation, we need to devise an objective function in order to determine the optimal settings for the PID controller. The PID_ AOVA function was established so that engineers could identify whether PID controller had the least amount of overshoot, the shortest rising time, or the fastest setting time.

This characteristic of the design of a PID controller ensures that the projected controller settings will result in a closed-loop system that is stable. The MATLAB code that constitutes the AOVA-PID controller system is connected to the Simulink model that was produced as a result of this. The proposed approach is carried out on a computer with a processing speed of 2.4 gigahertz

and 8 gigabytes of random access memory (RAM), which is an Intel Core i5-4700HQ model. The table that follows provides a summary of the general and specialized parameters.

Table 1- Parameter setting.

Elements	Value
Number of search parameters	3
Number of iterations	80
Dimension	5000
Domain search	0 – 10
ß	0.2
Γ	2.5
A	0.2
P1	0.6
P2	0.4
P3	0.6

Table (2) presents the parameter values of the PID controller that were obtained during the implementation period of the software part of each method. For the proposed system, the parameter values for each performance evaluation equation were extracted using the equation for each evaluation coefficient, i.e. (2), (3), (4) and (5). Table (3) presents the response step that we obtain when designing the emulator using Simulink, which is shown in Figure (8) as a model of how this emulator works. This model provided better results with respect to overshoot, settling time, rising time and peak value compared with other methods.

Table 2: PID parameter setting values.

Method	P	I	D
ZN_PID	98.9	200	12.3
PSO_PID	600	200	18.9
AVOA_PID ISE	6	8.7	7
AVOA_PID IAE	9	7.8	3
AVOA_PID ITSE	7	10	1
AVOA_PID ITAE	10	9	3.5

Table 3- Response step for the methods compared with the proposed system.

Method	Overshoot	Setting time	Rising time	Peak value
ZN_PID	12.2%	0.91 s	0.0706 s	1.12
PSO_PID	23.7%	0.204 s	0.051 s	1.24
AVOA_PID ISE	0%	7.54 s	12.5 s	0.999
AVOA_PID IAE	0%	15.7 s	8.94 s	0.998
AVOA_PID ITSE	0%	2.56 s	1.26 s	1
AVOA_PID ITAE	0%	12.2 s	7.45 s	0.999

In addition to the results mentioned in the previous tables 2 and 3 in which the comparison was based on the time scale or the time domain, Figure (4) shows the improvement path for all three system parameters on the basis of the evaluation equations for the error that is retrieved to the control unit to determine the extent of the improvement that occurred.

Compared with ITAE, ISE and IAE, the PID_AVOA ITSE-tuned system performs the best. It achieves 5.59% overshoot, fastest settling time (3.15 s) and rising time (0.431 s) and highest peak value (1.09).

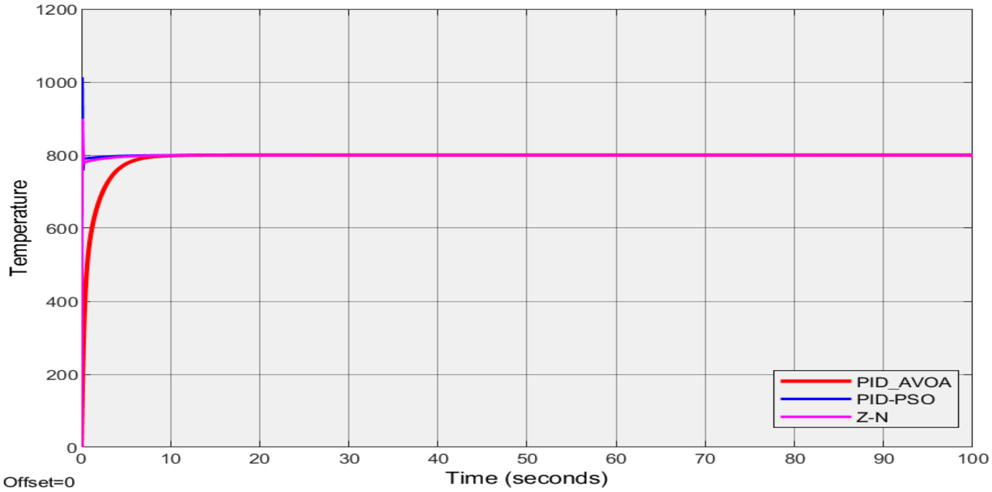

FIGURE 3. PID_AVOA ITSE compared with other approaches in terms of response indicator.

Figure (3) presents a comparison of the proposed system AVOA_PID with other methods. The highest value that must be reached is 800, as shown in the field (Temperature) on the coordinate line. The red color indicates that the proposed system provides more stability without overshooting. For the identical examination of the Temperature transfer function, the PSO and Z–N approaches exhibit maximal overshoot and excessive oscillations.

Table 4- Response step for the methods compared with the proposed system.

Method	Overshoot	Setting time	Rising time	Peak value
PID_AVOA ITSE	0%	2.56 s	1.26 s	1
Fuzzy control	0%	3.61 s	1.82 s	0.998

Figure (4) provides a comparison between system, AVOA_PID, and fuzzy control. The highest signal reaches 800, as shown in the field (temperature) on the coordinate line. The red figure in relation to the identical examination of the temperature function shows here that the proposed system is highly efficient by reaching a time of stability and rise less than the fuzzy logic. In adjusting the temperature the time factor plays an important role in reaching the required temperature.

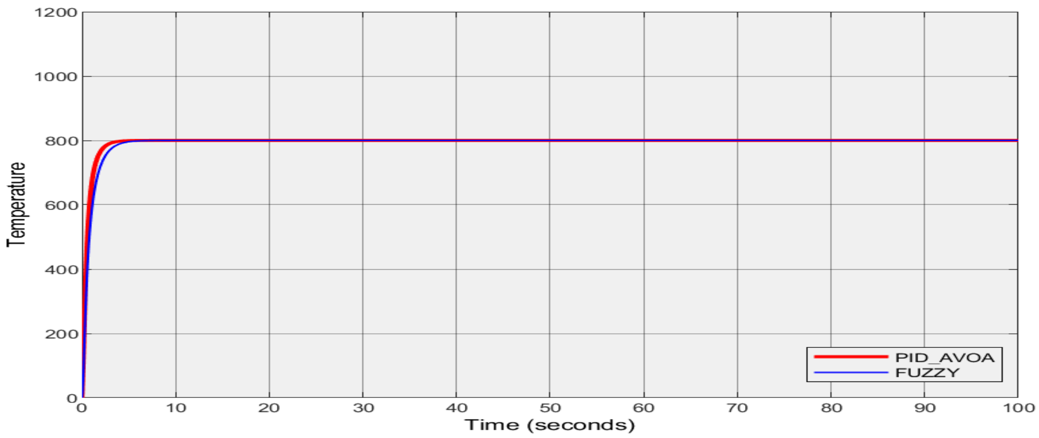

FIGURE 4. PID_AVOA ITSE compared with fuzzy control in terms of response indicator.

7. Conclusion:

It has been demonstrated that the use of the recommended system PID_AVOA for the purpose of optimizing the settings of a PID controller is superior than the utilization of conventional PID or other tuning procedures such as the PSO-based interface or the Z–N tuning method and fuzzy control. Based on our simulations, AVOA is able to independently adjust console settings without any human assistance. The performance of the proposed system was superior to that of four different AVOA releases when using IAE, ISE, ITSE, and ITAE as performance response indicators. The system was able to deliver optimal transient responses (rising time, stability time, decrease in settling time, and elimination at steady-state error) because it made advantage of parallel optimization parameter space.

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CONFLICTS OF INTEREST

None

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