Utilizing the Computation Intelligence Technique for Boiler Pressure Controlling

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Abstract. This paper aims to detect a damage in boiler of steam plant by using intelligence technique to improve the boiler performance. Experimental information is obtain by use an industrial boiler operating at AL-Dura power plant. This manuscript presents is to compare intelligence technique for boiler of steam power plant PID, ANFIS, PSO technique. Designing various pressure controllers to keep the boiler operating in normal conditions and enhance the efficiency. Those parameters are regulated through building a model and implementing in MATLAB, based on steam power plant requisite and the aims of the control. Results have shown that the PSO algorithm is optimal controlled and offers superior power plant performance from the PID controller. PSO, ANFIS and PID were implemented in AL–Dura power plant in Baghdad. Those techniques have been extensively utilized in numerous industry applications.

Keyword: ANFIS, PSO, control, PID.

1. Introduction:

Most of the electricity formed as of thermal power plant. An important component of thermal plant is a steam generation (boiler), it is a closed container which is made of high-quality steel where the steam is produced from the water by applying thermal from combustion of fuel such as coal, oil or gas. When a fuel is burning a surface of boiler is heating, hot gases generated in heating surface and exposed on one side and water or steam on the other. The steam collected over the surface of the water has been taken from boiler via superheater and afterwards, appropriate pipes to drive turbine for the electric generation or for some purpose in industrial application. The performance of steam power plant determine by performance of boiler[1]. Many of experimental and numerical researches were discussed on the boiler characteristics in several decades as S.Hosham (2018),(2019), which applied ANN for...
control of pressure, pressure, air:fuel ratio, flame, water level, gas available of boiler, this technique give agood agreement, and when compare between PID,ANN, the result give ANN a best performance than PID [2][3].

Rahul (2011) This paper discussed the 2 approaches, which are the PID controller and the fuzzy logic controller compared between them, the best results have been shown in the case of the use of the fuzzy logic controller. Maximal overshoot of approximately 9.35% for the fuzzy controller in comparison with 47.3% identified by the PID controller. The settling time which has been measured for the fuzzy controller at 7.18s and 10.14 in the PID controller, which has been utilized for controlling parameters like the pressure, which changes due to the changes of the circumstances [4].

Then Pranitachavan (2015), discussed controlling of superheated steam pressure in the thermal power plants with the use of the fuzzy logic controller. The fuzzy logic controller was advanced with the use of the PIC 16F-871 micro-controller which produces the desirable signals. MATLAB programming with the fuzzy control has been utilized for coping with issues that result from steam generators. Conventional controller PID can’t treat with the non-linearities of the system. In addition to that, this research discusses comparisons between the fuzzy controller and the conventional controller. In the case where the comparison concluded that fuzzy logic control has higher flexibility and needs a smaller amount of time compared to the conventional approach [5] As well as H. Aygun1 (2011) applied Particle Swarm Optimization based PID , FLC which are modern controllers, and classical PID controller are utilized to control the bed pressure of a circulating fluidized bed boiler and they are compared , Bed pressure is important parameters in a circulating fluidized bed boiler. Because the efficiency of the combustion enhances with rising the bed pressure and also harmful emissions are influenced with the bed pressure. Simulation results show that settling time in PSO-PID controller is lower than other controllers. PSOPID decreases overshoot like FLC but in classical PID controller overshoots are the biggest. In FLC there are no overshoot [6].

And D.Thangavelusamy (2015) Design and accomplishment of PI/PID controllers Based Particle Swarm Optimization apply to boiler element. Designing Coordinated PID Controller and tuning the parameter with the use of the (PSO), the Results obtained that controller provides more sufficient performance for each of the servo and the regulatory responses.

This study aims at controlling variables pressure of boiler of AL-Dora power plant in Baghdad that impacted maximal produced power and plant efficiency with the use of intelligent techniques and made a comparison between them [7].

2. Intelligent Control Techniques

2.1. Particle Swarm Optimization

PSO is a method for optimizing difficult numerical function by recruit or metaphor the social behavior of fish schools and flocks of birds. The most important PSO algorithm is founded by simplifying the social simulation model. The algorithm was planned the first time to emulate birds search for food which is simulated to be a cornfield vector. The bird would find food through united cooperation among birds Then, expand to contain multidimensional search. In PSO algorithm, each particle in swarm appear to be as a result of the trouble and it is resolute by its velocity and position.

For numbers of variable (n) in optimization task, a flock of particles are placed in the equal number of dimensional of search space at random selection positions and velocities in order to know their best magnitude for determining (Pbest) the greatest speed value and location in the specified dimensional space throughout the random movement of each part and at each iteration. Or, the velocity of both particles is fitted as to its own flying test and another particle flying experiment.
The particle can be represented [8], as:

\[ x_i = (x_{i,1}, x_{i,2}, x_{i,3}, \ldots, x_{i,n}) \]  

(1)

In n-dimensional space, the most excellent previous particle position as:

\[ P_{\text{best}_i} = (P_{\text{best}_{i,1}}, P_{\text{best}_{i,2}}, \ldots, P_{\text{best}_{i,n}}) \]  

(2)

The adapted velocity and location of both particles may be considered with the use of current distance and velocity from \((P_{\text{best},d})\) to \((g_{\text{best}})\) as illustrated in following formula as:

\[ \begin{align*}
V^{(\text{It}+1)}_{i,m} &= W \times V^{(\text{It})}_{i,m} + c_1 \times \text{rand} \times (P_{\text{best}_{i,m}} - x^{(\text{It})}_{i,m}) + c_2 \times \text{rand} \times (g_{\text{best}_m} - x^{(\text{It})}_{i,m}) \\
X^{(\text{It}+1)}_{i,m} &= X^{(\text{It})}_{i,m} + V^{(\text{It})}_{i,m}
\end{align*} \]  

(3)

(4)

Where \(i=1, 2, 3, \ldots, n\)

\(m=1, 2, 3, \ldots, d\)

\(n\) stands for the Number of particles.

Iter. stands for the Iterations pointer.

d stands for the Dimension.

W stands for the Inertia weight factor.

\(V^{(\text{It})}_{i,m}\) stands for the Particle (no. i) velocity at iteration It.

\(\text{rand}\) stands for a Random number between 0-1.

\(c_1, c_2\) stand for the Acceleration constant.

\(P_{\text{best}_i}\) stands for the Best previous position of the particle.

\(X^{(\text{It})}_{i,m}\) stands for the Particle i current position at iteration It.

\(g_{\text{best}_m}\) stands for the Best particle among all the particles in the population.

The integrated time weight square error (ITSE) is used for evaluating the coefficients.

\[ \text{ITSE} = \int_0^T t \cdot e^2(t) \, dt \]  

(5)
2.2. The Adaptive Network Based Fuzzy Inference System (ANFIS)

The ANFIS neuro-fuzzy controller has been implemented by Jang and employed Takagi – Sugeno – Kang (TSK) system fuzzy inference. Square nodes in ANFIS construction denote the limitation sets of the functions of membership of TSK fuzzy system. The circular nodes can be considered static / non-modifiable and present operations like the produce or the max/min computations. A hybrid learning rule has been utilized for increasing the speed of the parameter adaption. This utilization of the sequential least square in forward by-pass for identifying successive parameter, and back-propagation in backward pass for setting basis parameters up[9].

2.3. PID Controller

Genetic algorithms applied to analyze a range of engineering problems. By implementing this type of algorithms in the tuning of the PID. The common strategy of the PID control was discovered as one of the potential approaches as a result of its little costs, simple maintenance also easy in the control designs. Basically, variables of the PID controller are made up of 3 distinct variables, which are: integral (ki), proportionality (kp), in addition to the derivative values (kd). A proper setting of those variables is going to enhance the dynamic system response, improve system stability, and eliminate steady state error [9].

The most important PID control system construction has been illustrated in figure 1. The set point was changed, the error is going to be calculated between set point and actual output. Error signal, E(s), has been utilized for the production of proportionate, derivative, and integral actions, with resultant signals that have been weighted and summed for forming control signal, \(U_c(s)\), that has been applied to the particular model. After that, obtaining new signal of the output. This new real signal is going to be emitted to controller, and again, error signal is going to be computed. New control signal, \(U_c(s)\), is going to be transmitted to plant. This process is going to run in a continuous manner, to the point where the steady – state – error becomes near 0.

![Figure 1: PID control system](image-url)
3. Simulation Models of pressure

Pressure generate from boiler are similar to entering the turbine. In the case where the data attainment, shows that pressure must be <140 bar for avoiding the explosion.

![Simulation Models of Pressure](image)

**Figure 2: Simulation Models of Pressure**

4. Results of Simulink Model

Figure 3 and table 1 shows the pressure increase with time of the boiler in AL – Dura power plant, using (PSO,ANFIS,PID) This result give a small setting time in PSO technique than ANFIS,PID. But ANFIS is less overshoting comparer other methods.
Table 1: Results of comparison of intelligent technique of pressure

| Parameter | Rise Time | Settling Time | Peak | Peak Time | Overshoot |
|-----------|-----------|---------------|------|-----------|-----------|
| Pressure  |           |               |      |           |           |
| PSO       | 0.85      | 2             | 160  | 30        | 20        |
| ANFIS     | 3.4       | 4             | 135  | 30        | 5         |
| PID       | 2.6       | 18            | 180  | 30        | 40        |

Figure 3: The pressure of the boiler.

5. Conclusion

This paper applied to Computation intelligence technique to control of pressure of steam generation. In this study, a case study of the process control which takes the boiler was implemented with the use of the PSO, PID, and ANFIS. Initially, a mathematical system model has been developed and a traditional PID controller, PSO, ANFIS have been applied in it. Through comparing with PSO, PID, ANFIS controller, it has been shown that this approach enhanced the dynamic system efficiency in a more sufficient manner. PSO can be considered as the optimal one, due to the fact that it has given adequate performances and is known for its sufficient robustness. The conventional algorithm of the PSO. It utilizes only primary mathematical operators, and provides sufficient outputs in the noisy, static, and continuously varying environments. All those benefits result in implementing PSO in a wider range of the research areas. Lately, PSO approaches have been applied with success in numerous engineering and real-world issues as well.
Abbreviation

| PID          | Proportional-integral-derivative |
|--------------|----------------------------------|
| ANFIS        | Adaptive Neuro Fuzzy Inference System |
| PSO          | Particle Swarm Optimization      |

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