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Optimization of SCR Denitration Spraying Based on Support Vector Machine and Differential Evolution Algorithm

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Abstract: The paper focused on the boiler SCR DeNO_x system of power plant, and studied on optimal operation of the SCR DeNO_x system. According to the microscopic mechanism of SCR and based on lots of data analyzed by DCS records about SCR system, the main factors which affect the efficiency of DeNO_x has been got. Then built the nonlinear fitting model between SCR DeNO_x efficiency and operate parameters by Support Vector Machine, meantime, optimize the model quickly and effectively by differential evolution algorithm. Ultimately, we got the optimal operation parameters of SCR DeNO_x system which can make the efficiency of DeNO_x maximization. Experiments show that the proposed method is effective and feasible, and it not only provide a new thought for such problems about multi-parameter characteristics predictive modeling, but also provide guidance to field operations.

1. Introduction

At present, coal-fired power station boilers control NO_x emissions mainly by selective catalytic reduction (SCR) flue gas denitration technology. Higher denitration efficiency can be obtained by using the SCR system, but the effect is also easily affected by various factors such as ammonia supply, flue gas temperature, flue gas flow rate, NO_x removal rate, and catalyst dosage. Therefore, it is of great significance to explore the main factors affecting the denitration efficiency, and to optimize the operation parameters of the denitration system to obtain the optimal operation parameters of the denitration system.

This paper takes the SCR denitration system as the research object and studies the optimal operation of the system. According to the microscopic mechanism of denitration reaction, a large amount of data of denitration system operation is analyzed, and the main factors affecting the denitration efficiency are obtained. Then, the support model is used to establish the fitting model between denitration efficiency and various operating parameters, and efficient differential is adopted. And finally obtain the optimal adjustment parameters of the ammonia injection operation of the SCR denitration system under given conditions to maximize the SCR denitration efficiency. The model and method proposed in this paper can provide guidance for the parameter adjustment of field operators, and play an important role in reducing the operating cost of SCR technology and saving energy and reducing power consumption of power plants.



2. Analysis of main influencing factors of SCR denitration efficiency

There are many factors affecting the efficiency of SCR denitration, including ammonia supply, flue gas temperature, particle size, SCR reactor inlet NO_x concentration, catalyst dosage, and etc. The following focuses on the effects of ammonia-nitrogen ratio, flue gas temperature and reactor inlet NO_x concentration on denitration efficiency.

2.1 Effect of ammonia-nitrogen ratio on denitration efficiency

A sufficient amount of NH₃ is involved in the reaction to ensure that the NO_x in the flue gas is effectively removed, and thus the amount of ammonia supplied during the denitration reaction has a great influence on the entire reaction process. If the ammonia is too low, the denitration efficiency will be limited. If too much ammonia is added, the excess ammonia will easily react with the SO₂ in the flue gas to form hydrogen sulphate, which will cause ash and blockage in the boiler's subsequent equipment. And too much ammonia supply also increases the operating cost of the denitration system. Generally, the ratio of volumetric flow rate of ammonia to the concentration of NO_x is used to characterize the molar ratio of ammonia to nitrogen. And control NH₃/NO_x molar ratio below 1.2.

2.2 Effect of flue gas temperature on denitration efficiency

Flue gas temperature is decisive for the rate of catalytic reduction and catalyst activity. When the temperature of the flue gas is lowered, the activity of the catalyst is lowered, thereby reducing the denitration efficiency. At this time, NH₃ reacts with SO₂ in the flue gas to form ammonium sulfate which is highly liable to adhere to the surface of the catalyst, thereby further weakening the action of the catalyst. When the temperature of the flue gas rises, the denitration reaction rate rises rapidly, and the denitration efficiency increases. However, the continuous increase of temperature makes it easy for NH₃ to react with oxygen to form NO_x, which will lead to a decrease in denitration efficiency^[1-2]. The temperature of the flue gas is mainly affected by the boiler load. To ensure high denitration efficiency, the boiler load should be stabilized as much as possible.

2.3 Effect of SCR inlet NO_x concentration on denitration efficiency

The SCR inlet NO_x concentration is closely related to the combustion conditions of the boiler. Any change in combustion conditions will affect the concentration of NO_x. The following analysis from several important factors. (1) Burnout wind OFA has a greater impact on NO_x emissions, especially if low nitrogen burners are not installed. When the OFA burns out the wind, the amount of NO_x generated can be greatly reduced, and the denitration rate is significantly increased. (2) As the boiler load increases, the total NO_x production concentration increases slightly. (3) The oxygen content of the boiler is positively correlated with the excess air coefficient α ^[3-5], and the concentration of NO_x is increased first and then tends to change gently with the increase of α .

3. SCR denitration spray ammonia optimization model

In this paper, the SCR denitration efficiency is taken as the optimization target, and the denitration efficiency optimization model is a multi-input single-output system. The process of denitration efficiency prediction is to obtain the denitration efficiency from the input parameters, while the optimization process is to reverse the optimal input parameters from the optimal denitration efficiency. The historical operating parameters selected in this paper include: generator power, output of six coal mills, primary air temperature at the coal mill exit, six primary damper opening, six secondary damper opening, burner swing angle, and burnout damper Opening degree, total air volume, furnace outlet oxygen, total coal volume, and furnace outlet NO_x concentration.

Firstly, support vector machine modeling for denitrification efficiency prediction, then consider various practical constraints to optimize the denitration efficiency as the goal, to guide the actual denitration efficiency optimization adjustment operation. This paper uses an improved SMO training algorithm^[6-7]. In view of the choice of parameters c , σ and ϵ , the accuracy of SVM regression

estimation has a great influence. This paper uses differential evolution algorithm to automatically select the optimal parameters of SVM.

Differential Evolution Algorithm (DEA) is a simple and effective intelligent optimization calculation method^[8], which can directly use real number operation without complex coding and decoding process. The algorithm has many advantages such as strong robustness, fast convergence speed and good global search ability. The performance in dealing with many optimization problems is better than particle swarm optimization algorithm, genetic algorithm and ant colony algorithm.

The SCR denitration ammonia injection optimization system established in this paper first reads the historical data related to NO_x from the production real-time monitoring system (SIS) of the coal-fired power station, and establishes a fitting model of the SCR denitration efficiency function $S(X, T, K)$. The model reflects the recent operating characteristics of the SCR denitration system through timing updates, then the differential evolution algorithm and the established denitration efficiency prediction model are used to optimize the operating parameters, so that the SCR denitration efficiency of the power plant boiler is continuously optimized with the adjustment of operating parameters, and finally the maximum denitration efficiency is obtained.

4. Results and analysis

Based on the SIS system database, the support vector machine is used to establish the relational model of the unit load, reactor inlet NO_x concentration, ammonia flow rate, ammonia-air ratio, reactor differential pressure, outlet oxygen and other parameters and denitration efficiency. Based on the model, uses an improved differential evolution algorithm to maximize the denitrification efficiency for parameter optimization.

The results before and after optimization under full load conditions are shown in Table 1. The results verify the feasibility of support vector machine for denitration efficiency optimization modeling. The differential evolution algorithm can optimize the model with denitration efficiency as the target and can effectively improve the denitration efficiency of SCR.

Table 1. The comparison of results before and after optimization on full load conditions

Parameter	B-side SCR inlet NO _x concentration mg/Nm ³	A-side SCR inlet NO _x concentration mg/Nm ³	B-side ammonia flow Nm ³ /h	A-side ammonia flow Nm ³ /h	B-side ammonia air ratio %	A-side ammonia air ratio %	B-side SCR Pressure difference Pa	A-side SCR Pressure difference Pa	B-side outlet oxygen %	A-side outlet oxygen %	Denitration efficiency %
Before optimization	535.06	562.72	64.57	56.08	2.65	2.32	433.86	437.29	1.43	1.57	77.65
Optimized	516.81	527.34	65.83	59.14	2.62	2.41	423.79	428.15	1.78	2.29	85.32

5. Conclusion

(1) The denitration efficiency optimization model is a multiple input single output system. There are many factors affecting the efficiency of denitrification, and these parameters have strong coupling and nonlinear characteristics. For these complex processes, it is difficult to describe them with a simple mechanism model. In this paper, the influence of various parameters on the denitrification efficiency of SCR is fully considered. For the first time, the nonlinear fitting black box model between SCR denitration efficiency and multi-parameters is successfully established by using the combination of support vector machine and differential evolution algorithm. At the same time, the block diagram of SCR denitration ammonia optimization system is proposed, which lays a foundation for optimal control of SCR denitration system.

(2) In this paper, the influence of various operating parameters on the denitrification efficiency of SCR is fully considered. A high-precision NO_x prediction model is successfully constructed under multi-parametric characteristics, which provides a new idea for multi-parametric eigensystem prediction modeling.

(3) This paper designs a new improved differential evolution algorithm for the complex large-scale nonlinear model of SCR ammonia injection optimization. The algorithm can quickly and accurately obtain the global optimal solution, and obtain the system operating parameter value that maximizes the

denitration efficiency. The result can guide the actual optimization adjustment. Have a greater practical significance to the generation process.

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