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LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Économie

11

N° de publication :

LU509397

<https://patent.public.lu/fo-eregister-view/>

12

BREVET D'INVENTION

B1

21

N° de dépôt: LU509397

51

Int. Cl.:
B01D 53/34, F23J 1/00, F01N 1/00

22

Date de dépôt: 17/12/2024

30

Priorité:
19/09/2024 CN 202411308458.3

73

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Date de mise à disposition du public: 19/06/2025

72

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Date de délivrance: 19/06/2025

DX

Date d'expiration: 17/12/2030

74

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IP SHIELD – 1616 Luxembourg (Luxembourg)

85

Date d'entrée en phase nationale:

86

N° de dépôt de la demande internationale:

54

METHOD FOR CONTROLLING NITROGEN OXIDES IN FLUE GAS FROM THE HEAT RECOVERY BOILER OF A COMBINED CYCLE UNIT.

57

The present invention provides a method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit, comprising: determining the target value of nitrogen oxide content, the flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas of the heat recovery boiler, and the current urea solution supply rate; then determining the target value of nitrogen oxide emissions, the actual value of nitrogen oxide emissions, and the required increase in the amount of urea; subsequently determining the required increase in the urea solution supply rate and the target urea solution supply rate to be achieved; using the required increase in the urea solution supply rate as the feedforward input of a PID controller to adjust the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, so that the actual value of nitrogen oxide content equals the target value. This effectively eliminates the blindness and lag in the control process, thereby significantly improving the control accuracy and response speed.

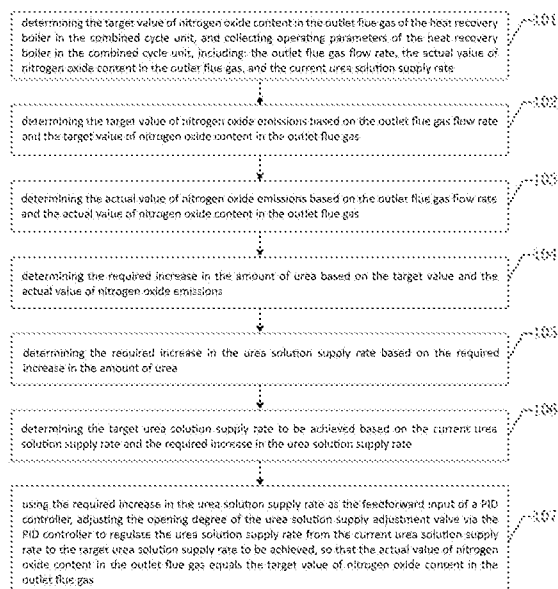


FIG.1

METHOD FOR CONTROLLING NITROGEN OXIDES IN FLUE GAS FROM THE HEAT RECOVERY BOILER OF A COMBINED CYCLE UNIT

Technical Field

5 The present invention relates to the technical field of nitrogen oxide control in flue gas, and in particular, to a method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit.

Background Technology

10 With increasingly stringent requirements for emission standards in power plants both domestically and internationally, there is a need for power plants to further reduce the nitrogen oxide content in the outlet flue gas of heat recovery boilers in combined cycle units. Currently, the adopted control method to reduce the nitrogen oxide content in the outlet flue gas of such boilers is to directly use the deviation
15 between the actual value and the target value of nitrogen oxide content as the feedforward input of a PID controller, which then adjusts the urea solution supply rate.

 However, due to inherent limitations of this method, it exhibits blindness and lag during the control process, leading to poor control accuracy and slow response speed.

20 Summary of the Invention

 The present invention provides a method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit to address the deficiencies of poor control accuracy and slow response speed in existing nitrogen oxide control methods.

25 In a first aspect, the present invention provides a method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit, comprising:

 determining the target value of nitrogen oxide content in the outlet flue gas of the heat recovery boiler in the combined cycle unit, and collecting operating parameters of the heat recovery boiler in the combined cycle unit, including: the outlet

flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas, and the current urea solution supply rate;

determining the target value of nitrogen oxide emissions based on the outlet flue gas flow rate and the target value of nitrogen oxide content in the outlet flue gas;

5 determining the actual value of nitrogen oxide emissions based on the outlet flue gas flow rate and the actual value of nitrogen oxide content in the outlet flue gas;

determining the required increase in the amount of urea based on the target value and the actual value of nitrogen oxide emissions;

10 determining the required increase in the urea solution supply rate based on the required increase in the amount of urea;

determining the target urea solution supply rate to be achieved based on the current urea solution supply rate and the required increase in the urea solution supply rate;

15 using the required increase in the urea solution supply rate as the feedforward input of a PID controller, adjusting the opening degree of the urea solution supply adjustment valve via the PID controller to regulate the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, so that the actual value of nitrogen oxide content in the outlet flue gas equals the target value of nitrogen oxide content in the outlet flue gas.

20 According to the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit provided by the present invention, determining the required increase in the amount of urea based on the target value and the actual value of nitrogen oxide emissions, comprising:

25 determining the difference between the target value and the actual value of nitrogen oxide emissions;

determining the required increase in the amount of urea based on the difference and a preset formula;

wherein the preset formula is:

$$\Delta M = (M_2 - M_1) / 1000 / 180 \times 120 / 1000$$

30 where ΔM represents the required increase in the amount of urea, M_1 represents

the target value of nitrogen oxide emissions, and M_2 represents the actual value of nitrogen oxide emissions.

According to the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit provided by the present invention,
5 determining the required increase in the urea solution supply rate based on the required increase in the amount of urea, comprising:

determining the efficiency of ammonia decomposition by the pyrolysis furnace, the reaction efficiency of ammonia with nitrogen oxides, the mass concentration of the urea solution, and the density of the urea solution at the current temperature;

10 inputting the required increase in the amount of urea, the efficiency of ammonia decomposition by the pyrolysis furnace, the reaction efficiency of ammonia with nitrogen oxides, the mass concentration of the urea solution, and the density of the urea solution at the current temperature into the formula for determining the required increase in the urea solution supply rate to obtain the required increase in the urea
15 solution supply rate;

wherein the formula for determining the required increase in the urea solution supply rate is:

$$\Delta t = \Delta M / N_1 / N_2 / q / p$$

where ΔM represents the required increase in the amount of urea, N_1 represents
20 the efficiency of ammonia decomposition by the pyrolysis furnace, N_2 represents the reaction efficiency of ammonia with nitrogen oxides, q represents the mass concentration of the urea solution, and p represents the density of the urea solution at the current temperature.

According to the method for controlling nitrogen oxides in flue gas from the heat
25 recovery boiler of a combined cycle unit provided by the present invention, determining the target urea solution supply rate to be achieved, comprising:

$$t = t_0 + \Delta t$$

where t represents the target urea solution supply rate to be achieved, t_0
represents the current urea solution supply rate, and Δt represents the required
30 increase in the urea solution supply rate.

According to the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit provided by the present invention, determining the target value of nitrogen oxide emissions as:

$$M_1=f \times Q_1$$

5 and determining the actual value of nitrogen oxide emissions as:

$$M_2=f \times Q_2$$

where M_1 represents the target value of nitrogen oxide emissions, M_2 represents the actual value of nitrogen oxide emissions, f represents the outlet flue gas flow rate, Q_1 represents the target value of nitrogen oxide content in the outlet flue gas, and Q_2 represents the actual value of nitrogen oxide content in the outlet flue gas.

According to the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit provided by the present invention, determining the target value of nitrogen oxide content in the outlet flue gas, comprising:

15 determining the maximum allowable environmental emission concentration and the fuel type, wherein the fuel type includes natural gas, coal, and biomass;

based on unit efficiency and economic cost, comprehensively determining the target value of nitrogen oxide content in the outlet flue gas as 50% of the maximum allowable emission concentration.

20 According to the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit provided by the present invention, adjusting the opening degree of the urea solution supply adjustment valve to regulate the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, comprising:

25 determining the correspondence between the opening degree of the adjustment valve and the urea solution supply rate;

adjusting the opening degree of the adjustment valve at a preset speed based on the target increase rate and the correspondence.

In a second aspect, the present invention provides a device for controlling
30 nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit,

comprising:

a collection module, configured to determine the target value of nitrogen oxide content in the outlet flue gas of the heat recovery boiler of a combined cycle unit and to collect operating parameters of the heat recovery boiler of the combined cycle unit, including: the outlet flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas, and the current urea solution supply rate;

a determination module, configured to determine the target value of nitrogen oxide emissions based on the outlet flue gas flow rate and the target value of nitrogen oxide content in the outlet flue gas; determine the actual value of nitrogen oxide emissions based on the outlet flue gas flow rate and the actual value of nitrogen oxide content in the outlet flue gas; determine the required increase in the amount of urea based on the target value and the actual value of nitrogen oxide emissions; determine the required increase in the urea solution supply rate based on the required increase in the amount of urea; and determine the target urea solution supply rate to be achieved based on the current urea solution supply rate and the required increase in the urea solution supply rate;

an adjustment module, configured to use the required increase in the urea solution supply rate as the feedforward input of a PID controller, and to adjust the opening degree of the urea solution supply adjustment valve via the PID controller to regulate the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, so that the actual value of nitrogen oxide content in the outlet flue gas equals the target value of nitrogen oxide content in the outlet flue gas.

In a third aspect, the present invention further provides an electronic device comprising a memory, a processor, and a computer program stored in the memory and executable on the processor, wherein the processor executes the program to implement any of the aforementioned methods for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit.

In a fourth aspect, the present invention further provides a non-transitory computer-readable storage medium storing a computer program, wherein the

computer program is executed by a processor to implement any of the aforementioned methods for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit.

In a fifth aspect, the present invention further provides a computer program
5 product comprising a computer program, wherein the computer program is executed by a processor to implement any of the aforementioned methods for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit.

The method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit provided by the present invention includes:
10 determining the target value of nitrogen oxide content in the outlet flue gas of the heat recovery boiler of a combined cycle unit and collecting operating parameters of the heat recovery boiler, including: the outlet flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas, and the current urea solution supply rate;
determining the target value of nitrogen oxide emissions based on the outlet flue gas
15 flow rate and the target value of nitrogen oxide content in the outlet flue gas;
determining the actual value of nitrogen oxide emissions based on the outlet flue gas flow rate and the actual value of nitrogen oxide content in the outlet flue gas;
determining the required increase in the amount of urea based on the target value and the actual value of nitrogen oxide emissions; determining the required increase in
20 the urea solution supply rate based on the required increase in the amount of urea;
determining the target urea solution supply rate to be achieved based on the current urea solution supply rate and the required increase in the urea solution supply rate;
using the required increase in the urea solution supply rate as the feedforward input of a PID controller, and adjusting the opening degree of the urea solution supply
25 adjustment valve via the PID controller to regulate the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, so that the actual value of nitrogen oxide content in the outlet flue gas equals the target value. By using the required increase in the urea solution supply rate as the feedforward input of the PID controller, the method effectively eliminates
30 blindness and lag in the control process, thereby significantly improving control

accuracy and response speed.

Description of the Drawings

To provide a clearer explanation of the technical solutions in the present invention or the existing technology, the following introduces the drawings used in the description of embodiments or existing technology. It should be understood that the drawings described below represent some embodiments of the present invention, and for those skilled in the art, other drawings can be derived from these without involving inventive effort.

FIG.1 is a flowchart of the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit provided by the embodiments.

FIG.2 is a structural schematic diagram of the device for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit provided by the embodiments.

FIG.3 is a structural schematic diagram of the electronic device provided by the embodiments.

Detailed Description

To make the objectives, technical solutions, and advantages of the present invention clearer, the following provides a detailed and complete description of the technical solutions in the present invention with reference to the accompanying drawings. Evidently, the described embodiments are part of the present invention rather than all of its embodiments. Based on the embodiments of the present invention, all other embodiments that a person skilled in the art could obtain without creative effort are within the scope of protection of the present invention.

FIG.1 is a flow diagram of the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit provided by this embodiment.

As shown in FIG.1, an embodiment of the present invention provides a method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit, comprising:

101. determining the target value of nitrogen oxide content in the outlet flue gas of the heat recovery boiler in the combined cycle unit, and collecting operating parameters of the heat recovery boiler in the combined cycle unit, including: the outlet flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas, and
5 the current urea solution supply rate.

In a specific implementation, the target value of nitrogen oxide content in the outlet flue gas refers to the most reasonable emission level, determined based on environmental emission standards and other factors. Specifically, the process involves first determining the maximum allowable environmental emission concentration and
10 the fuel type, wherein the fuel type includes natural gas, coal, and biomass. Based on unit efficiency and economic cost, a comprehensive determination is made such that the target value of nitrogen oxide content in the outlet flue gas is set at 50% of the maximum allowable emission concentration. Different fuel types correspond to different combustion rates, and different unit efficiencies and economic costs also vary.
15 Thus, by comprehensively considering the fuel type, unit efficiency, and economic cost, the target value of nitrogen oxide content in the outlet flue gas is set within the maximum allowable emission concentration range to ensure optimal rationality.

Simultaneously, parameters such as the outlet flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas, and the current urea solution supply
20 rate are collected, typically through sensors.

102. determining the target value of nitrogen oxide emissions based on the outlet flue gas flow rate and the target value of nitrogen oxide content in the outlet flue gas.

Determine the target value of nitrogen oxide emissions using Formula (1):

$$M_1 = f \times Q_1 \quad (1)$$

25 where M_1 represents the target value of nitrogen oxide emissions, f represents the outlet flue gas flow rate, and Q_1 represents the target value of nitrogen oxide content in the outlet flue gas.

The unit of M_1 is mg/h, Q_1 is mg/m³, and f is m³/h.

103. determining the actual value of nitrogen oxide emissions based on the outlet

flue gas flow rate and the actual value of nitrogen oxide content in the outlet flue gas.

Determine the actual value of nitrogen oxide emissions using Formula (2):

$$M_2 = f \times Q_2 \quad (2)$$

where M_2 represents the actual value of nitrogen oxide emissions, f represents
5 the outlet flue gas flow rate, and Q_2 represents the actual value of nitrogen oxide
content in the outlet flue gas.

The unit of M_2 is mg/h, Q_2 is mg/m³, and f is m³/h.

104. determining the required increase in the amount of urea based on the target
value and the actual value of nitrogen oxide emissions.

10 Determine the difference between the target value and the actual value of
nitrogen oxide emissions. Based on this difference and a preset formula, determine
the required increase in the amount of urea;

The preset formula is Formula (3):

$$\Delta M = (M_2 - M_1) / 1000 / 180 \times 120 / 1000 \quad (3)$$

15 where ΔM represents the required increase in the amount of urea, M_1 represents
the target value of nitrogen oxide emissions, M_2 represents the actual value of nitrogen
oxide emissions, and ΔM is in mg/h.

105. determining the required increase in the urea solution supply rate based on
the required increase in the amount of urea.

20 First, determine the efficiency of ammonia decomposition by the pyrolysis
furnace, the reaction efficiency of ammonia with nitrogen oxides, the mass
concentration of the urea solution, and the density of the urea solution at the current
temperature. Then, input the required increase in the amount of urea, the efficiency
of ammonia decomposition by the pyrolysis furnace, the reaction efficiency of
25 ammonia with nitrogen oxides, the mass concentration of the urea solution, and the
density of the urea solution at the current temperature into the formula for
determining the required increase in the urea solution supply rate to obtain the
required increase in the urea solution supply rate.

The formula for determining the required increase in the urea solution supply rate
30 is Formula (4):

$$\Delta t = \Delta M / N_1 / N_2 / q / p \quad (4)$$

where ΔM represents the required increase in the amount of urea, N_1 represents the efficiency of ammonia decomposition by the pyrolysis furnace, N_2 represents the reaction efficiency of ammonia with nitrogen oxides, q represents the mass concentration of the urea solution, p represents the density of the urea solution at the current temperature, and Δt is in m^3/h .

106. determining the target urea solution supply rate to be achieved based on the current urea solution supply rate and the required increase in the urea solution supply rate.

Determine the target urea solution supply rate to be achieved using Formula (5):

$$t = t_0 + \Delta t \quad (5)$$

where t represents the target urea solution supply rate, t_0 represents the current urea solution supply rate, and Δt represents the required increase in the urea solution supply rate. The unit of t is m^3/h .

107. using the required increase in the urea solution supply rate as the feedforward input of a PID controller, adjusting the opening degree of the urea solution supply adjustment valve via the PID controller to regulate the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, so that the actual value of nitrogen oxide content in the outlet flue gas equals the target value of nitrogen oxide content in the outlet flue gas.

Specifically, determine the correspondence between the opening degree of the adjustment valve and the urea solution supply rate. Based on the target increase rate and the correspondence, adjust the opening degree of the adjustment valve at a preset speed. By controlling the opening degree of the valve, the urea solution supply rate can be adjusted. Due to the correspondence between the valve opening degree and the supply rate, the supply rate can be accurately and stably controlled.

This embodiment does not directly use the deviation between the actual value and the target value of nitrogen oxide content as the feedforward input of the PID controller. Instead, the required increase in the urea solution supply rate is first calculated and then used as the feedforward input of the PID controller. This effectively

eliminates blindness and lag in the control process, thereby significantly improving control accuracy and response speed.

Based on the same overall inventive concept, the present invention also protects a device for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit. Below is a description of the device for controlling nitrogen oxides in flue gas from the heat recovery boiler provided by the present invention. This device corresponds to and can be cross-referenced with the previously described method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit.

FIG.2 illustrates a structural schematic diagram of the device for controlling nitrogen oxides in flue gas from the heat recovery boiler provided by this embodiment.

As shown in FIG.2, an embodiment provides a device for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit, comprising:

a collection module 201, configured to determine the target value of nitrogen oxide content in the outlet flue gas of the heat recovery boiler of a combined cycle unit and to collect operating parameters of the heat recovery boiler of the combined cycle unit, including: the outlet flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas, and the current urea solution supply rate;

a determination module 202, configured to determine the target value of nitrogen oxide emissions based on the outlet flue gas flow rate and the target value of nitrogen oxide content in the outlet flue gas; determine the actual value of nitrogen oxide emissions based on the outlet flue gas flow rate and the actual value of nitrogen oxide content in the outlet flue gas; determine the required increase in the amount of urea based on the target value and the actual value of nitrogen oxide emissions; determine the required increase in the urea solution supply rate based on the required increase in the amount of urea; and determine the target urea solution supply rate to be achieved based on the current urea solution supply rate and the required increase in the urea solution supply rate;

an adjustment module 203, configured to use the required increase in the urea solution supply rate as the feedforward input of a PID controller, and to adjust the

opening degree of the urea solution supply adjustment valve via the PID controller to regulate the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, so that the actual value of nitrogen oxide content in the outlet flue gas equals the target value of nitrogen oxide content
 5 in the outlet flue gas.

Further, the determination module 202 in this embodiment is specifically used for:

determining the difference between the target value and the actual value of nitrogen oxide emissions;

10 determining the required increase in the amount of urea based on the difference and a preset formula;

wherein the preset formula is:

$$\Delta M = (M_2 - M_1) / 1000 / 180 \times 120 / 1000$$

where ΔM represents the required increase in the amount of urea, M_1 represents
 15 the target value of nitrogen oxide emissions, and M_2 represents the actual value of nitrogen oxide emissions.

Further, the determination module 202 in this embodiment is specifically used for:

determining the efficiency of ammonia decomposition by the pyrolysis furnace,
 20 the reaction efficiency of ammonia with nitrogen oxides, the mass concentration of the urea solution, and the density of the urea solution at the current temperature;

inputting the required increase in the amount of urea, the efficiency of ammonia decomposition by the pyrolysis furnace, the reaction efficiency of ammonia with nitrogen oxides, the mass concentration of the urea solution, and the density of the
 25 urea solution at the current temperature into the formula for determining the required increase in the urea solution supply rate to obtain the required increase in the urea solution supply rate;

wherein the formula for determining the required increase in the urea solution supply rate is:

30
$$\Delta t = \Delta M / N_1 / N_2 / q / p$$

where ΔM represents the required increase in the amount of urea, N_1 represents the efficiency of ammonia decomposition by the pyrolysis furnace, N_2 represents the reaction efficiency of ammonia with nitrogen oxides, q represents the mass concentration of the urea solution, and p represents the density of the urea solution at the current temperature.

Further, the determination module 202 in this embodiment is specifically used for:

$$t=t_0+\Delta t$$

where t represents the target urea solution supply rate to be achieved, t_0 represents the current urea solution supply rate, and Δt represents the required increase in the urea solution supply rate.

Further, the determination module 202 in this embodiment is specifically used for:

$$M_1=f\times Q_1$$

and determining the actual value of nitrogen oxide emissions as:

$$M_2=f\times Q_2$$

where M_1 represents the target value of nitrogen oxide emissions, M_2 represents the actual value of nitrogen oxide emissions, f represents the outlet flue gas flow rate, Q_1 represents the target value of nitrogen oxide content in the outlet flue gas, and Q_2 represents the actual value of nitrogen oxide content in the outlet flue gas.

Further, the collection module 201 in this embodiment is specifically used for:

determining the maximum allowable environmental emission concentration and the fuel type, wherein the fuel type includes natural gas, coal, and biomass;

based on unit efficiency and economic cost, comprehensively determining the target value of nitrogen oxide content in the outlet flue gas as 50% of the maximum allowable emission concentration.

Further, the adjustment module 203 in this embodiment is specifically used for:

determining the correspondence between the opening degree of the adjustment valve and the urea solution supply rate;

adjusting the opening degree of the adjustment valve at a preset speed based on the target increase rate and the correspondence.

FIG.3 illustrates a structural schematic diagram of the electronic device provided by this embodiment.

As shown in FIG.3, the electronic device may include: a processor 310, a communication interface 320, a memory 330, and a communication bus 340, where

5 the processor 310, communication interface 320, and memory 330 communicate with each other via the communication bus 340. The processor 310 can invoke logical instructions stored in the memory 330 to execute the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit, which includes: Determining the target value of nitrogen oxide content in the outlet flue gas

10 of the heat recovery boiler and collecting the operating parameters of the heat recovery boiler, including: the outlet flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas, and the current urea solution supply rate; Determining the target value of nitrogen oxide emissions based on the outlet flue gas flow rate and the target value of nitrogen oxide content in the outlet flue gas;

15 Determining the actual value of nitrogen oxide emissions based on the outlet flue gas flow rate and the actual value of nitrogen oxide content in the outlet flue gas; Determining the required increase in the amount of urea based on the target value and the actual value of nitrogen oxide emissions; Determining the required increase in the urea solution supply rate based on the required increase in the amount of urea;

20 Determining the target urea solution supply rate to be achieved based on the current urea solution supply rate and the required increase in the urea solution supply rate; Using the required increase in the urea solution supply rate as the feedforward input of a PID controller, and adjusting the opening degree of the urea solution supply adjustment valve via the PID controller to regulate the urea solution supply rate from

25 the current urea solution supply rate to the target urea solution supply rate to be achieved, so that the actual value of nitrogen oxide content in the outlet flue gas equals the target value.

Additionally, the logical instructions stored in the memory 330 can be implemented in the form of software function modules. When sold or used as an

30 independent product, they can be stored on a computer-readable storage medium.

From this understanding, the technical solutions of the present invention, or the parts that contribute to the existing technology, can essentially be embodied in the form of software products. Such a computer software product is stored on a storage medium and includes several instructions that enable a computer device (which can be a
5 personal computer, server, or network device, etc.) to execute all or part of the steps of the methods in various embodiments of the present invention. The aforementioned storage media include: USB drives, portable hard drives, read-only memory (ROM), random access memory (RAM), magnetic disks, optical disks, and various other media capable of storing program code.

10 In another aspect, the present invention also provides a computer program product. The computer program product includes a computer program that can be stored on a non-transitory computer-readable storage medium. When executed by a processor, the computer program enables the computer to execute the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined
15 cycle unit provided by the aforementioned methods. The method includes:
Determining the target value of nitrogen oxide content in the outlet flue gas of the heat recovery boiler of a combined cycle unit, and collecting the operating parameters of the heat recovery boiler, including: the outlet flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas, and the current urea solution supply rate;
20 Determining the target value of nitrogen oxide emissions based on the outlet flue gas flow rate and the target value of nitrogen oxide content in the outlet flue gas;
Determining the actual value of nitrogen oxide emissions based on the outlet flue gas flow rate and the actual value of nitrogen oxide content in the outlet flue gas;
Determining the required increase in the amount of urea based on the target value
25 and the actual value of nitrogen oxide emissions; Determining the required increase in the urea solution supply rate based on the required increase in the amount of urea;
Determining the target urea solution supply rate to be achieved based on the current urea solution supply rate and the required increase in the urea solution supply rate;
Using the required increase in the urea solution supply rate as the feedforward input
30 of a PID controller, and adjusting the opening degree of the urea solution supply

adjustment valve via the PID controller to regulate the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, so that the actual value of nitrogen oxide content in the outlet flue gas equals the target value.

5 In yet another aspect, the present invention also provides a non-transitory computer-readable storage medium storing a computer program. When executed by a processor, the computer program implements the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit as provided by the aforementioned methods. The method includes: Determining the target value
10 of nitrogen oxide content in the outlet flue gas of the heat recovery boiler of a combined cycle unit, and collecting the operating parameters of the heat recovery boiler, including: the outlet flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas, and the current urea solution supply rate; Determining the target value of nitrogen oxide emissions based on the outlet flue gas flow rate and
15 the target value of nitrogen oxide content in the outlet flue gas; Determining the actual value of nitrogen oxide emissions based on the outlet flue gas flow rate and the actual value of nitrogen oxide content in the outlet flue gas; Determining the required increase in the amount of urea based on the target value and the actual value of nitrogen oxide emissions; Determining the required increase in the urea solution
20 supply rate based on the required increase in the amount of urea; Determining the target urea solution supply rate to be achieved based on the current urea solution supply rate and the required increase in the urea solution supply rate; Using the required increase in the urea solution supply rate as the feedforward input of a PID controller, and adjusting the opening degree of the urea solution supply adjustment
25 valve via the PID controller to regulate the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, so that the actual value of nitrogen oxide content in the outlet flue gas equals the target value.

The device embodiments described above are merely illustrative. The units described as separate components may or may not be physically separated, and
30 components shown as units may or may not be physical units. They can be located in

one place or distributed across multiple network units. Specific parts or all modules can be selected to implement the objectives of the embodiments based on actual needs. Those skilled in the art can understand and implement these without creative effort.

5 From the descriptions of the embodiments above, it is clear to those skilled in the art that each embodiment can be implemented by means of software in conjunction with a necessary general hardware platform or entirely by hardware. Based on this understanding, the technical solutions described above, or the parts that contribute to the existing technology, can essentially be embodied in the form of software
10 products. Such a computer software product can be stored on a computer-readable storage medium, such as ROM, RAM, magnetic disks, or optical disks, and includes several instructions to enable a computer device (e.g., a personal computer, server, or network device) to execute all or parts of the methods of the various embodiments.

 Finally, it should be noted that the above-described embodiments are merely
15 intended to illustrate the technical solutions of the present invention and are not intended to limit them. Despite the detailed descriptions of the present invention with reference to the foregoing embodiments, those skilled in the art should understand that modifications can still be made to the technical solutions described in the foregoing embodiments, or equivalent replacements can be made for some of the
20 technical features therein, without departing from the spirit and scope of the technical solutions of the embodiments of the present invention.

CLAIMS

1. A method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit, wherein comprising:

determining the target value of nitrogen oxide content in the outlet flue gas of the heat recovery boiler in the combined cycle unit, and collecting operating parameters of the heat recovery boiler in the combined cycle unit, including: the outlet flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas, and the current urea solution supply rate;

determining the target value of nitrogen oxide emissions based on the outlet flue gas flow rate and the target value of nitrogen oxide content in the outlet flue gas;

determining the actual value of nitrogen oxide emissions based on the outlet flue gas flow rate and the actual value of nitrogen oxide content in the outlet flue gas;

determining the required increase in the amount of urea based on the target value and the actual value of nitrogen oxide emissions;

determining the required increase in the urea solution supply rate based on the required increase in the amount of urea;

determining the target urea solution supply rate to be achieved based on the current urea solution supply rate and the required increase in the urea solution supply rate;

using the required increase in the urea solution supply rate as the feedforward input of a PID controller, adjusting the opening degree of the urea solution supply adjustment valve via the PID controller to regulate the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, so that the actual value of nitrogen oxide content in the outlet flue gas equals the target value of nitrogen oxide content in the outlet flue gas.

2. The method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit according to claim 1, wherein determining the required increase in the amount of urea based on the target value and the actual value of

nitrogen oxide emissions, comprising:

determining the difference between the target value and the actual value of nitrogen oxide emissions;

determining the required increase in the amount of urea based on the difference
5 and a preset formula;

wherein the preset formula is:

$$\Delta M = (M_2 - M_1) / 1000 / 180 \times 120 / 1000$$

where ΔM represents the required increase in the amount of urea, M_1 represents the target value of nitrogen oxide emissions, and M_2 represents the actual value of
10 nitrogen oxide emissions.

3. The method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit according to claim 1, wherein determining the required increase in the urea solution supply rate based on the required increase in the amount
15 of urea, comprising:

determining the efficiency of ammonia decomposition by the pyrolysis furnace, the reaction efficiency of ammonia with nitrogen oxides, the mass concentration of the urea solution, and the density of the urea solution at the current temperature;

inputting the required increase in the amount of urea, the efficiency of ammonia
20 decomposition by the pyrolysis furnace, the reaction efficiency of ammonia with nitrogen oxides, the mass concentration of the urea solution, and the density of the urea solution at the current temperature into the formula for determining the required increase in the urea solution supply rate to obtain the required increase in the urea solution supply rate;

25 wherein the formula for determining the required increase in the urea solution supply rate is:

$$\Delta t = \Delta M / N_1 / N_2 / q / p$$

where ΔM represents the required increase in the amount of urea, N_1 represents the efficiency of ammonia decomposition by the pyrolysis furnace, N_2 represents the
30 reaction efficiency of ammonia with nitrogen oxides, q represents the mass

concentration of the urea solution, and p represents the density of the urea solution at the current temperature.

4. The method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit according to claim 3, wherein determining the target urea solution supply rate to be achieved, comprising:

$$t=t_0+\Delta t$$

- where t represents the target urea solution supply rate to be achieved, t_0 represents the current urea solution supply rate, and Δt represents the required increase in the urea solution supply rate.

5. The method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit according to claim 1, wherein determining the target value of nitrogen oxide emissions as:

$$M_1=f\times Q_1$$

and determining the actual value of nitrogen oxide emissions as:

$$M_2=f\times Q_2$$

- where M_1 represents the target value of nitrogen oxide emissions, M_2 represents the actual value of nitrogen oxide emissions, f represents the outlet flue gas flow rate, Q_1 represents the target value of nitrogen oxide content in the outlet flue gas, and Q_2 represents the actual value of nitrogen oxide content in the outlet flue gas.

6. The method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit according to claim 1, wherein determining the target value of nitrogen oxide content in the outlet flue gas, comprising:

determining the maximum allowable environmental emission concentration and the fuel type, wherein the fuel type includes natural gas, coal, and biomass;

- based on unit efficiency and economic cost, comprehensively determining the target value of nitrogen oxide content in the outlet flue gas as 50% of the maximum allowable emission concentration.

7. The method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit according to claim 1, wherein adjusting the opening degree of the urea solution supply adjustment valve to regulate the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, comprising:

determining the correspondence between the opening degree of the adjustment valve and the urea solution supply rate;

adjusting the opening degree of the adjustment valve at a preset speed based on the target increase rate and the correspondence.

8. A device for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit, wherein comprising:

a collection module, configured to determine the target value of nitrogen oxide content in the outlet flue gas of the heat recovery boiler of a combined cycle unit and to collect operating parameters of the heat recovery boiler of the combined cycle unit, including: the outlet flue gas flow rate, the actual value of nitrogen oxide content in the outlet flue gas, and the current urea solution supply rate;

a determination module, configured to determine the target value of nitrogen oxide emissions based on the outlet flue gas flow rate and the target value of nitrogen oxide content in the outlet flue gas; determine the actual value of nitrogen oxide emissions based on the outlet flue gas flow rate and the actual value of nitrogen oxide content in the outlet flue gas; determine the required increase in the amount of urea based on the target value and the actual value of nitrogen oxide emissions; determine the required increase in the urea solution supply rate based on the required increase in the amount of urea; and determine the target urea solution supply rate to be achieved based on the current urea solution supply rate and the required increase in the urea solution supply rate;

an adjustment module, configured to use the required increase in the urea solution supply rate as the feedforward input of a PID controller, and to adjust the opening degree of the urea solution supply adjustment valve via the PID controller to

regulate the urea solution supply rate from the current urea solution supply rate to the target urea solution supply rate to be achieved, so that the actual value of nitrogen oxide content in the outlet flue gas equals the target value of nitrogen oxide content in the outlet flue gas.

5

9. An electronic device comprising a memory, a processor, and a computer program stored in the memory and executable on the processor, wherein the processor executes the program to implement the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit according to any one of claims 1 to 7.

10

10. A non-transitory computer-readable storage medium storing a computer program, wherein the computer program is executed by a processor to implement the method for controlling nitrogen oxides in flue gas from the heat recovery boiler of a combined cycle unit according to any one of claims 1 to 7.

15

REVENDICATIONS

1. Procédé de contrôle des oxydes d'azote dans les gaz de combustion provenant de la chaudière de récupération de chaleur d'une unité à cycle combiné, comprenant :

5 Déterminer la valeur cible de la teneur en oxydes d'azote dans les gaz de combustion en sortie de la chaudière de récupération de chaleur de l'unité à cycle combiné, et collecter les paramètres de fonctionnement de ladite chaudière, notamment : le débit des gaz de combustion en sortie, la valeur réelle de la teneur en oxydes d'azote dans les gaz de combustion en sortie, et le débit actuel
10 d'approvisionnement en solution d'urée ;

Déterminer la valeur cible des émissions d'oxydes d'azote sur la base du débit des gaz de combustion en sortie et de la valeur cible de la teneur en oxydes d'azote dans les gaz de combustion en sortie ;

Déterminer la valeur réelle des émissions d'oxydes d'azote sur la base du débit
15 des gaz de combustion en sortie et de la valeur réelle de la teneur en oxydes d'azote dans les gaz de combustion en sortie ;

Déterminer l'augmentation nécessaire de la quantité d'urée sur la base de la valeur cible et de la valeur réelle des émissions d'oxydes d'azote ;

Déterminer l'augmentation nécessaire du débit d'approvisionnement en solution
20 d'urée sur la base de l'augmentation nécessaire de la quantité d'urée ;

Déterminer le débit cible d'approvisionnement en solution d'urée à atteindre sur la base du débit actuel d'approvisionnement en solution d'urée et de l'augmentation nécessaire du débit d'approvisionnement en solution d'urée ;

Utiliser l'augmentation nécessaire du débit d'approvisionnement en solution
25 d'urée comme entrée anticipée pour un régulateur PID, ajuster l'ouverture de la vanne de réglage d'approvisionnement en solution d'urée via le régulateur PID afin de réguler le débit d'approvisionnement en solution d'urée du débit actuel au débit cible à atteindre, de manière à ce que la valeur réelle de la teneur en oxydes d'azote dans les gaz de combustion en sortie soit égale à la valeur cible de la teneur en oxydes d'azote

dans les gaz de combustion en sortie.

2. Procédé selon la revendication 1, caractérisé en ce que la détermination de l'augmentation nécessaire de la quantité d'urée sur la base de la valeur cible et de la valeur réelle des émissions d'oxydes d'azote comprend :

Déterminer la différence entre la valeur cible et la valeur réelle des émissions d'oxydes d'azote ;

Déterminer l'augmentation nécessaire de la quantité d'urée sur la base de cette différence et d'une formule prédéfinie ;

La formule prédéfinie est la suivante :

$$\Delta M = (M_2 - M_1) / 1000 / 180 \times 120 / 1000$$

où ΔM représente l'augmentation nécessaire de la quantité d'urée, M_1 représente la valeur cible des émissions d'oxydes d'azote, et M_2 représente la valeur réelle des émissions d'oxydes d'azote.

3. Procédé selon la revendication 1, caractérisé en ce que la détermination de l'augmentation nécessaire du débit d'approvisionnement en solution d'urée sur la base de l'augmentation nécessaire de la quantité d'urée comprend :

Déterminer le rendement de décomposition de l'ammoniac par le four de pyrolyse, l'efficacité de la réaction de l'ammoniac avec les oxydes d'azote, la concentration massique de la solution d'urée et la densité de la solution d'urée à la température actuelle ;

Entrer l'augmentation nécessaire de la quantité d'urée, le rendement de décomposition de l'ammoniac par le four de pyrolyse, l'efficacité de la réaction de l'ammoniac avec les oxydes d'azote, la concentration massique de la solution d'urée et la densité de la solution d'urée à la température actuelle dans la formule pour déterminer l'augmentation nécessaire du débit d'approvisionnement en solution d'urée, afin d'obtenir cette augmentation nécessaire ;

La formule pour déterminer l'augmentation nécessaire du débit d'approvisionnement en solution d'urée est la suivante :

$$\Delta t = \Delta M / N_1 / N_2 / q / p$$

où ΔM représente l'augmentation nécessaire de la quantité d'urée, N_1 représente le rendement de décomposition de l'ammoniac par le four de pyrolyse, N_2 représente l'efficacité de la réaction de l'ammoniac avec les oxydes d'azote, q représente la concentration massique de la solution d'urée, et p représente la densité de la solution d'urée à la température actuelle.

4. Procédé selon la revendication 3, caractérisé en ce que la détermination du débit cible d'approvisionnement en solution d'urée à atteindre comprend :

$$t = t_0 + \Delta t$$

où t représente le débit cible d'approvisionnement en solution d'urée à atteindre, t_0 représente le débit actuel d'approvisionnement en solution d'urée, et Δt représente l'augmentation nécessaire du débit d'approvisionnement en solution d'urée.

5. Procédé selon la revendication 1, caractérisé en ce que la détermination de la valeur cible des émissions d'oxydes d'azote est exprimée comme suit :

$$M_1 = f \times Q_1$$

et la détermination de la valeur réelle des émissions d'oxydes d'azote est exprimée comme suit :

$$M_2 = f \times Q_2$$

où M_1 représente la valeur cible des émissions d'oxydes d'azote, M_2 représente la valeur réelle des émissions d'oxydes d'azote, f représente le débit des gaz de combustion en sortie, Q_1 représente la valeur cible de la teneur en oxydes d'azote dans les gaz de combustion en sortie, et Q_2 représente la valeur réelle de la teneur en oxydes d'azote dans les gaz de combustion en sortie.

6. Procédé selon la revendication 1, caractérisé en ce que la détermination de la valeur cible de la teneur en oxydes d'azote dans les gaz de combustion en sortie comprend :

Déterminer la concentration maximale admissible d'émissions environnementales et le type de combustible, le type de combustible comprenant le

gaz naturel, le charbon et la biomasse ;

En fonction de l'efficacité de l'unité et du coût économique, déterminer globalement la valeur cible de la teneur en oxydes d'azote dans les gaz de combustion en sortie comme étant 50 % de la concentration maximale admissible d'émissions.

5

7. Procédé selon la revendication 1, caractérisé en ce que l'ajustement de l'ouverture de la vanne de réglage d'approvisionnement en solution d'urée pour réguler le débit d'approvisionnement en solution d'urée du débit actuel au débit cible à atteindre comprend :

10 Déterminer la correspondance entre l'ouverture de la vanne de réglage et le débit d'approvisionnement en solution d'urée ;

Ajuster l'ouverture de la vanne de réglage à une vitesse prédéfinie en fonction de la vitesse d'augmentation cible et de la correspondance.

15 8. Dispositif de contrôle des oxydes d'azote dans les gaz de combustion provenant de la chaudière de récupération de chaleur d'une unité à cycle combiné, comprenant :

Un module de collecte, configuré pour déterminer la valeur cible de la teneur en oxydes d'azote dans les gaz de combustion en sortie de la chaudière de récupération de chaleur d'une unité à cycle combiné, et pour collecter les paramètres de
20 fonctionnement de ladite chaudière, notamment : le débit des gaz de combustion en sortie, la valeur réelle de la teneur en oxydes d'azote dans les gaz de combustion en sortie, et le débit actuel d'approvisionnement en solution d'urée ;

Un module de détermination, configuré pour déterminer la valeur cible des émissions d'oxydes d'azote sur la base du débit des gaz de combustion en sortie et de
25 la valeur cible de la teneur en oxydes d'azote dans les gaz de combustion en sortie ; déterminer la valeur réelle des émissions d'oxydes d'azote sur la base du débit des gaz de combustion en sortie et de la valeur réelle de la teneur en oxydes d'azote dans les gaz de combustion en sortie ; déterminer l'augmentation nécessaire de la quantité d'urée sur la base de la valeur cible et de la valeur réelle des émissions d'oxydes
30 d'azote ; déterminer l'augmentation nécessaire du débit d'approvisionnement en

solution d'urée sur la base de l'augmentation nécessaire de la quantité d'urée ; et déterminer le débit cible d'approvisionnement en solution d'urée à atteindre sur la base du débit actuel et de l'augmentation nécessaire du débit d'approvisionnement en solution d'urée ;

- 5 Un module d'ajustement, configuré pour utiliser l'augmentation nécessaire du débit d'approvisionnement en solution d'urée comme entrée anticipée pour un régulateur PID, et pour ajuster l'ouverture de la vanne de réglage d'approvisionnement en solution d'urée via le régulateur PID afin de réguler le débit d'approvisionnement en solution d'urée du débit actuel au débit cible à atteindre, de manière à ce que la
- 10 valeur réelle de la teneur en oxydes d'azote dans les gaz de combustion en sortie soit égale à la valeur cible de la teneur en oxydes d'azote dans les gaz de combustion en sortie.

9. Dispositif électronique comprenant une mémoire, un processeur et un
- 15 programme informatique stocké dans la mémoire et exécutable sur le processeur, caractérisé en ce que le processeur exécute le programme pour mettre en œuvre le procédé de contrôle des oxydes d'azote dans les gaz de combustion provenant de la chaudière de récupération de chaleur d'une unité à cycle combiné selon l'une quelconque des revendications 1 à 7.

- 20
10. Support de stockage informatique non transitoire contenant un programme informatique, caractérisé en ce que le programme informatique est exécuté par un processeur pour mettre en œuvre le procédé de contrôle des oxydes d'azote dans les gaz de combustion provenant de la chaudière de récupération de chaleur d'une unité
- 25 à cycle combiné selon l'une quelconque des revendications 1 à 7.

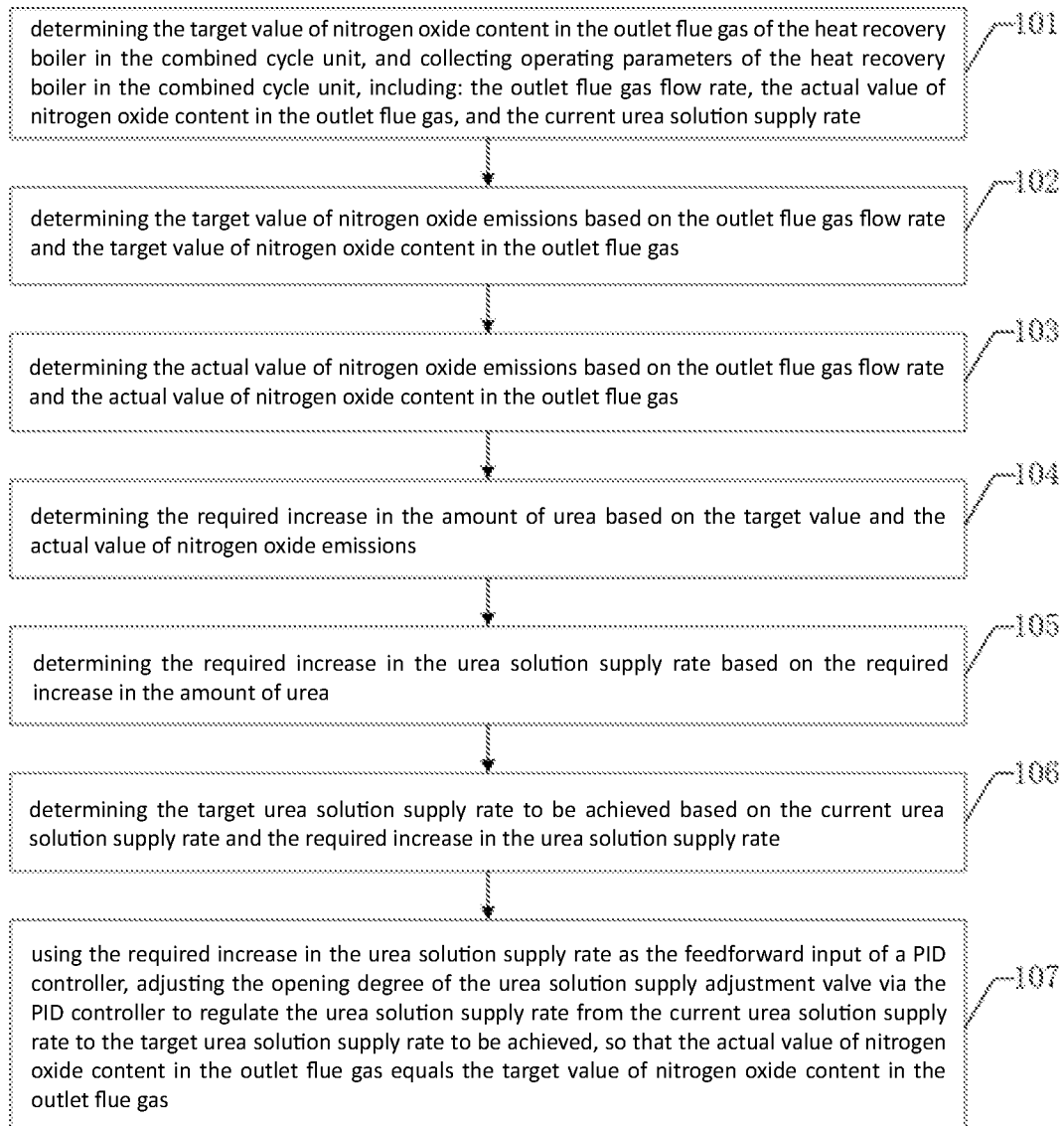


FIG.1

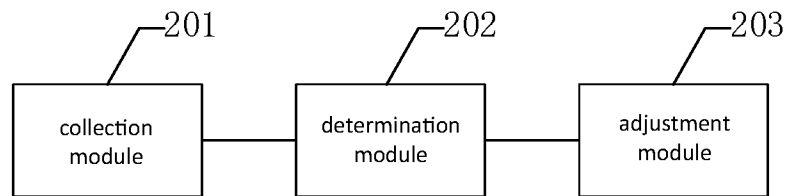


FIG.2

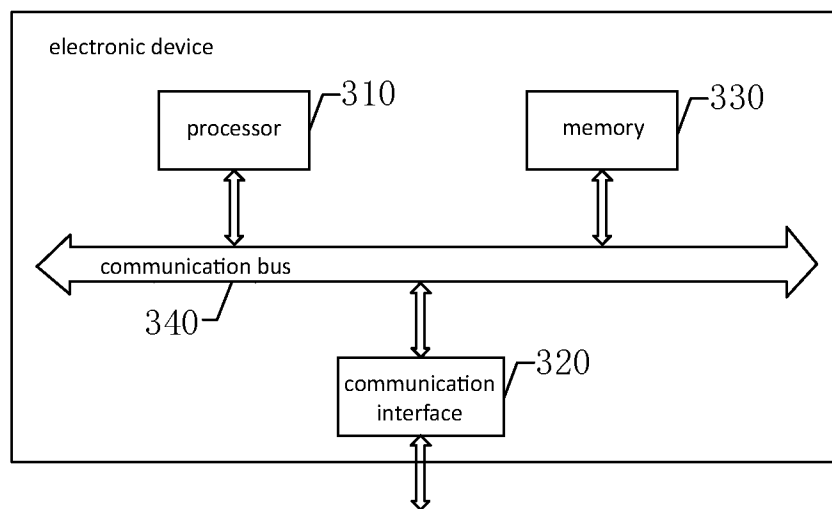


FIG.3