(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 836 163 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
16.06.2021 Bulletin 2021/24

(21) Application number: **19920615.2**

(22) Date of filing: **08.11.2019**

(51) Int Cl.:
G21C 17/10 *(2006.01)*

(86) International application number:
PCT/CN2019/116776

(87) International publication number:
WO 2020/186776 (24.09.2020 Gazette 2020/39)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
KH MA MD TN

(30) Priority: **15.03.2019 CN 201910199423**

(71) Applicants:
- **China Nuclear Power Operations Co., Ltd.**
  Shenzhen, Guangdong 518000 (CN)
- **China General Nuclear Power Corporation**
  Shenzhen, Guangdong 518028 (CN)
- **CGN Power Co., Ltd.**
  Shenzen, Guangdong 518028 (CN)

(72) Inventors:
- **ZHANG, Jun**
  Shenzhen, Guangdong 518000 (CN)
- **GAO, Fuling**
  Shenzhen, Guangdong 518000 (CN)
- **LIU, Meijun**
  Shenzhen, Guangdong 518000 (CN)
- **LI, Shengmao**
  Shenzhen, Guangdong 518000 (CN)
- **SUN, Bo**
  Shenzhen, Guangdong 518000 (CN)
- **LUO, Hongbo**
  Shenzhen, Guangdong 518000 (CN)
- **WANG, Bin**
  Shenzhen, Guangdong 518000 (CN)
- **CAI, Dashui**
  Shenzhen, Guangdong 518000 (CN)
- **YOU, Dailun**
  Shenzhen, Guangdong 518000 (CN)

(74) Representative: **Westphal, Mussgnug Patentanwälte & Partner mbB**
Werinherstraße 79
81541 München (DE)

(54) NUCLEAR POWER PLANT REACTOR CONTROL ROD ADDRESSING APPARATUS AND METHOD

(57) The present disclosure relates a nuclear power plant reactor control rod addressing device and the method thereof. The device includes a plurality of control rods, a driving power, lifting coils LC, and a voltage detector. The control rod includes a rod position probe and a rod stroke cover. The rod position probe and the lifting coil LC are disposed on the rod stroke cover. The rod position probe and the lifting coil LC are coaxially disposed. The rod position probe includes a secondary coil. The driving power is respectively connected to each of the lifting coils LC. The voltage detector is respectively connected to the secondary coil of each of the rod position probes. The driving power is configured to selectively energize one lifting coil LC such that the one lifting coil LC generates a first induced magnetic field. The secondary coil arranged coaxially with the one lifting coil LC is configured to generate a first induced voltage under the action of the first induced magnetic field. The voltage detector is configured to detect the first induced voltage to complete addressing of the control rod. The implementation of the present disclosure may reduce workload of the operator, reduce risk of human failure, reduce risk of communication failure, and greatly improve work efficiency and safety.

EP 3 836 163 A1

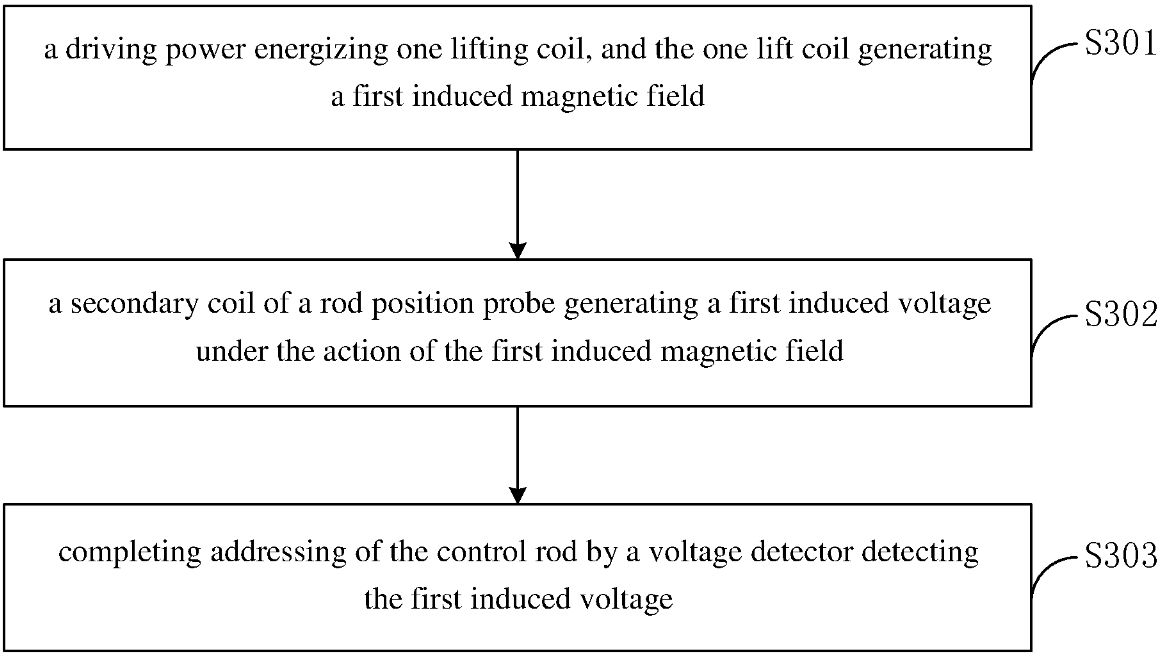
a driving power energizing one lifting coil, and the one lift coil generating a first induced magnetic field
S301
a secondary coil of a rod position probe generating a first induced voltage under the action of the first induced magnetic field
S302
completing addressing of the control rod by a voltage detector detecting the first induced voltage
S303

FIG. 3

Description

FIELD

[0001] The present invention relates to a nuclear power plant field, and more particularly, to a nuclear power plant reactor control rod addressing device and method thereof.

BACKGROUND

[0002] A control rod control system (RGL) is one of the special systems for nuclear power plants, and includes a rod control system and a rod position measurement system. Cables of the RGL span a reactor bridge to connect equipments on two sides. During a refueling and overhaul process, in order to open a reactor cover, all joints of the rod control cables and the rod test cables must be disconnected, and the cables must be reconnected when the refueling process is finished and the cover is closed to ensure availability of the RGL.

[0003] For example, in M310 and CRP1000 reactors, there are 61 rod control cables and 61 test cables. In order to ensure correct connections of the rod control cables and the rod test cables, a control rod addressing test must be performed in a cooling shutdown mode of a waste heat removal system, to confirm that there is no crossover in the connections. The current addressing test method is as follows:

S1, locking all rods except a first rod in a rod bundle, and raising the rod bundle by 10 steps;
S2, confirming that the measured rod position of the first rod in the rod bundle being increased by 8 steps (the smallest unit is 8 steps);
S3, unlocking the locked rods;
S4, locking all the rods except a second rod in the rod bundle, and raising the rod bundle by 10 steps;
S5, confirming that the measured rod position of the second rod in the rod bundle being increased by 8 steps (the smallest unit is 8 steps);
S6, according to the above-mentioned method, completing the rod raising of all single rods in the rod bundle, and confirming the corresponding measured rod position changes;
S7, according to the above-mentioned method, completing the control rod addressing of all the rod bundles, and confirming that a rod control channel and a rod measurement channel correspond one by one.

[0004] Although the existing method can complete the test, it has the following disadvantages:

1. A master operator is required to perform a large number of operations, which increases burden on the operators, increases risk of human failure, and is not conducive to the control of the unit status;
2. Control rods have moved, and reactivity of a primary loop is changed, which is not conducive to reactivity control;
3. It needs to communicate with the operator many times, which increases risk of communication failure;
4. The operator needs to perform a large number of unit status control work such as temperature rise and pressure rise, which leads to multiple interruptions of the addressing test, resulting in the addressing test lasting for 5 to 20 hours, thus increasing the uncertainty of the test.

SUMMARY

[0005] A technical problem to be solved by the present disclosure is to provide a nuclear power plant reactor control rod addressing device and method thereof in view of the above-mentioned defects in the related art.

[0006] A technical solution adopted by the present disclosure to solve the technique problem is to provide a nuclear power plant reactor control rod addressing device which includes a plurality of control rods, a driving power, lifting coils LC, and a voltage detector. The control rod includes a rod position probe and a rod stroke cover; the rod position probe and the lifting coils LC are mounted on the rod stroke cover, and the rod position probe and the lifting coils LC are coaxially disposed; the rod position probe includes a secondary coil.

[0007] The driving power is respectively connected to each of the lifting coils LC; the voltage detector is respectively connected to the secondary coil of each of the rod position probes.

[0008] The driving power is configured to selectively energize one lifting coil LC such that the one lifting coil LC generates a first induced magnetic field. The secondary coil arranged coaxially with the one lifting coil LC is configured to generate a first induced voltage under the action of the first induced magnetic field and the voltage detector is configured to detect the first induced voltage to complete addressing of the control rod; wherein the addressing is to check connectivity of a rod control channel and a rod measurement channel of the control rod to thereby determine one-to-one correspondence between the rod control channel and the rod measurement channel.

[0009] Further, in the nuclear power plant reactor control rod addressing device, the rod position probe further includes a primary coil; and the primary coil is coaxially disposed with the secondary coil; and the primary coil is configured to be energized by an alternating current (AC) power supply and generate a second induced magnetic field; the secondary coil is configured to generate a second induced voltage under the action of the second induced magnetic field; and the voltage detector is configured to detect the first induced voltage and the second induced voltage to complete the addressing of the control rod.

[0010] Further, in the nuclear power plant reactor control rod addressing device, the rod position probe further includes an auxiliary coil; the auxiliary coil is coaxially disposed with the primary coil; the auxiliary coil is connected to the AC power supply; and the auxiliary coil is configured to generate a third induced voltage under the action of the second induced magnetic field to allow the AC power supply to adjust its output current according to the third induced voltage.

[0011] Further, in the nuclear power plant reactor control rod addressing device, the voltage detector is an MCP22 encoding module; and a terminal 10 of the MCP22 encoding module is connected to the secondary coil.

[0012] The present disclosure further provides a nuclear power plant reactor control rod addressing method, including: a driving power energizing one lifting coil LC, such that the one lifting coil LC generates a first induced magnetic field; a secondary coil of a rod position probe generating a first induced voltage under the action of the first induced magnetic field; completing addressing of the control rod by a voltage detector detecting the first induced voltage; wherein the addressing is to check connectivity of a rod control channel and a rod measurement channel of the control rod, to determine one-to-one correspondence between the rod control channel and the rod measurement channel.

[0013] Further, in the nuclear power plant reactor control rod addressing method, the driving power energizing the one lifting coil LC includes the driving power energizing the one lifting coil LC by inputting a preset test current.

[0014] Further, in the nuclear power plant reactor control rod addressing method, completing addressing of the control rod by a voltage detector detecting the first induced voltage includes: determining whether the first induced voltage is larger than a preset induced voltage; if the first induced voltage is larger than the preset induced voltage, confirming that the rod position probe corresponds to the one lifting coil LC; and if the first induced voltage is not larger than the preset induced voltage, confirming that the rod position probe does not correspond to the one lifting coil LC.

[0015] Further, in the nuclear power plant reactor control rod addressing method, before the driving power energizing the one lifting coil LC, the method further includes: energizing the primary coil of the rod position probe by an alternating current (AC) power supply such that the primary coil of the rod position probe generates a second induced magnetic field and the secondary coil generates a second induced voltage under the action of the second induced magnetic field, whereby the completing the addressing of the control rod by a voltage detector detecting the first induced voltage includes completing the addressing of the control rod by the voltage detector detecting the first induced voltage and the second induced voltage.

[0016] Further, in the nuclear power plant reactor control rod addressing method, after the secondary coil generating the second induced voltage under the action of the second induced magnetic field, the method further includes: generating a Gray code according to the second induced voltage and determining a corresponding rod position of the rod position probe.

[0017] Further, in the nuclear power plant reactor control rod addressing method, the method further includes energizing a primary coil of the rod probe by an alternating current (AC) power supply such that the primary coil of the rod probe generates a second induced magnetic field; an auxiliary coil of the rod probe generating a third induced voltage under the second induced magnetic field, by; and the AC power supply adjusting its output current according to the third induced voltage.

[0018] The nuclear power plant reactor control rod addressing device and the method thereof provided by the present disclosure have the following beneficial effects. The device includes a plurality of control rods, a driving power, lifting coils LC, and a voltage detector. The control rod includes a rod position probe and a rod stroke cover. The rod position probe and the lifting coil LC are disposed on the rod stroke cover. The rod position probe and the lifting coil LC are coaxially disposed. The rod position probe includes a secondary coil. The driving power is respectively connected to each of the lifting coils LC. The voltage detector is respectively connected to the secondary coil of each of the rod position probes. The driving power is configured to selectively energize one lifting coil LC such that the one lifting coil LC generates a first induced magnetic field. The secondary coil arranged coaxially with the one lifting coil LC is configured to generate a first induced voltage under the action of the first induced magnetic field. The voltage detector is configured to detect the first induced voltage to complete addressing of the control rod. The implementation of the present disclosure may reduce workload of the operator, reduce risk of human failure, reduce risk of communication failure, and greatly improve work efficiency and safety.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The drawings involved in the embodiments of the present invention will be briefly introduced below.

Fig. 1 is a structural illustration view of a rod position probe in accordance with an embodiment in the present disclosure.

Fig. 2 is a structural illustration view of a nuclear power plant reactor control rod addressing device in accordance with an embodiment in the present disclosure.

Fig. 3 is a flow chart of a nuclear power plant reactor control rod addressing method in accordance with an embodiment in the present disclosure.

Fig. 4 is a flow chart of a nuclear power plant reactor control rod addressing method in accordance with an embodiment in the present disclosure.

Fig. 5 is a flow chart of an output current adjustment in accordance with an embodiment in the present disclosure.

Fig. 6 is a graph of a test result in accordance with an embodiment in the present disclosure.

DETAILED DESCRIPTION

[0020] In order to have a clearer understanding of the technical features, objectives and effects of the present disclosure, the specific embodiments of the present disclosure will now be described in detail with reference to the accompanying drawings.

Embodiment

[0021] A nuclear power plant reactor control rod addressing device of this embodiment includes a plurality of control rods, a driving power, lifting coils LC, and a voltage detector. Each of the control rods is provided with a lifting coil LC, but it is necessary to ensure that the control rod and the lifting coil have a preset corresponding relationship.

[0022] Fig. 1 shows a structural illustration view of a rod position probe 10. The rod position probe 10 includes a fixed flange 101, a connector 102, a primary coil 103, a shielding cover 104, a coil support 105, a secondary coil 106, an auxiliary coil 107, an adjustment spring 108, and an intermediate washer 109. Preferably, The rod position probe 10 includes five secondary coils 106 and two auxiliary coils 107. The primary coil 103, the secondary coils 106, and the auxiliary coils 107 are all wound on the coil support 105. The primary coil 103 is connected to an alternating current (AC) power supply through the connector 102. The voltage detector is respectively connected to the secondary coils 106 of each rod probe 10. The intermediate washers 109 are spaced arranged between the primary coil 103, the secondary coil 106, and the auxiliary coil 107. The fixed flange 101 is mounted at one end of the rod position probe 10. The adjusting spring 108 is arranged adjacent to the fixed flange 101.

[0023] Referring to Fig. 2, the control rod includes a rod position probe 10 and a rod stroke cover 20. The driving coil 30 includes a lifting coil LC, a moving coil MG, and a clamping coil SG. The rod position probe 10, the lifting coil LC, the moving coil MG, and the clamping coil SG are mounted on the rod stroke cover 20. The rod position probe 10, the lifting coil LC, the moving coil MG, and the clamping coil SG are coaxially disposed. The driving power is connected to each of the lifting coils LC respectively. As an option, the voltage detector is an MCP22 encoding module, and a terminal 10 of the MCP22 encoding module is connected to the secondary coil 106.

[0024] During the addressing process, the driving power selectively turns on one of the lifting coils LC, that is, all other control rods except the control rod to be tested are blocked, and one of the lifting coils LC is selected and input with a preset test current, for example, a preset test current of 41.6A. The lifting coil LC generates a first induced magnetic field under the action of the preset test current. Meanwhile, the secondary coil 106 arranged coaxially with the lifting coil LC generates a first induced voltage under the action of the first induced magnetic field. Secondary coils 106 of the other rod position probes 10 arranged on different axis from the lifting coil LC generate induced voltages under the action of the first induced magnetic field. However, the effect of the magnetic field generated by the other rod position probes 10 is greatly weakened due to the different axis and the long distance. Therefore, the induced voltages generated by the other rod position probes 10 are much smaller than the first induced voltage. The voltage detector may determine whether the secondary coil 106 corresponds to the energized lifting coil LC by detecting the magnitude of the first induced voltage. The secondary coil of which the first induced voltage is much larger than other induced voltages is the coil corresponding to the lifting coil LC. Then, it can be determined that whether the rod position probe 10 corresponds to the driving coil 30, and the addressing of the control rod is completed.

[0025] Further, the above-mentioned operations are repeated to complete the addressing of all control rods.

[0026] In this embodiment, a preset test current is applied to the lifting coil LC to generate a first induced magnetic field, and then the addressing of the control rod is completed according to the induced voltage generated by the secondary coil 106. The whole process does not need to move the control rod, which can greatly reduce the operator's operation amount, reduce the risk of human failure, reduce the risk of communication failure, and greatly improve work efficiency and safety.

Embodiment

[0027] On the basis of the above-mentioned embodiment, the primary coil 103 and the secondary coil 106 of the rod position probe 10 of the nuclear power plant reactor control rod addressing device of this embodiment are coaxially disposed, and the primary coil 103 is connected to the AC power supply through the connector 102.

[0028] In the addressing process, a sine wave alternating current is supllied to the primary coil 103 in this embodiment. The primary coil 103 generates a second induced magnetic field when being energized by the AC power supply. The secondary coil 106 generates a second induced voltage under the action of the second induced magnetic field. The second induced voltages generated by the secondary coils 106 of all rod position probes 10 are recorded. Further, the driving power selectively turns on one of the lifting coils LC, that is, all other control rods except the control rod to be tested are blocked. One of the lifting coils LC is selected and input with a preset test current, for example, a preset test current of 41.6A. The lifting coil LC generates a first induced magnetic field under the action of the preset test current. Meanwhile, the secondary coil 106 arranged coaxially with the lifting coil LC generates a first induced voltage under the action of the first induced magnetic field. Secondary coils 106 of the other rod position probes 10 arranged on different axis from the lifting coil LC generate induced voltages under the action of the first induced magnetic field. However, the effect of the magnetic field is greatly weakened due to the different axis and the long distance. Therefore, the induced voltages are much smaller than the first induced voltage. After the test is finished, the voltage detector can complete the addressing of the control rod by detecting the first induced voltage and the second induced voltage, that is, the addressing of the control rod is completed based on the difference between the first induced voltage and the second induced voltage.

[0029] Further, the above-mentioned operations are repeated to complete the addressing of all control rods.

[0030] In this embodiment, the addressing of the control rod is completed based on the difference between the first induced voltage and the second induced voltage. The whole process does not need to move the control rod, which greatly reduces the operator's operation amount, reduces the risk of human failure, reduces the risk of communication failure, and greatly improves work efficiency and safety.

[0031] In some embodiments, the rod position probe 10 of the nuclear power plant reactor control rod addressing device further includes one or more auxiliary coils 107 which are coaxially disposed with the primary coil 103, and the auxiliary coils 107 are connected to the AC power supply. The auxiliary coil 107 generates a third induced voltage under the action of the second induced magnetic field. The AC power supply adjusts the output current according to the third induced voltage.

Embodiment

[0032] As shown in Fig. 3, the nuclear power plant reactor control rod addressing method of this embodiment is applied to the above-mentioned nuclear power plant reactor control rod addressing device. A structure of the addressing device for the control rod of the nuclear power plant reactor may refer to the above-mentioned embodiments. Specifically, the addressing method for the control rod of the nuclear power plant reactor includes:

S301, energying one lifting coil LC by a driving power, and generating a first induced magnetic field by the one lifting coil LC. The energying one lifting coil LC by the driving power includes energying one lifting coil LC by the driving power and inputting with a preset test current, that is, blocking all other control rods except the control rod to be tested, and inputting with a preset test current, for example, a preset test current of 41.6A.

S302, generating a first induced voltage by the secondary coil 106 of the rod position probe 10 under the action of the first induced magnetic field. The secondary coil 106 arranged coaxially with the one lifting coil LC generates a first induced voltage under the action of the first induced magnetic field. Secondary coils 106 of the other rod position probes 10 arranged on different axis from the one lifting coil LC generate induced voltages under the action of the first induced magnetic field. However, the effect of the first magnetic field is greatly weakened due to the different axis and the long distance between the other rod position probes 10 and the one lifting coil LC. Therefore, the induced voltages are much smaller than the first induced voltage.

S303, detecting the first induced voltage by the voltage detector to complete the addressing of the control rod. The voltage detector may determine whether the secondary coil 106 corresponds to the energized lifting coil LC by detecting the magnitude of the first induced voltage. The secondary coil of which the first induced voltage is much larger than other induced voltages is the coil corresponding to the lifting coil LC. Then, it can be determined that whether the rod position probe 10 corresponds to the driving coil 30, so that the addressing of the control rod is completed.

[0033] In some embodiments, the detecting the first induced voltage by the voltage detector to complete the addressing of the control rod includes:

Determining whether the first induced voltage is larger than a preset induced voltage. The preset induced voltage is less than the induced voltage generated by the secondary coil 106 which is coaxial with the lifting coil LC. Meanwhile, the preset induced voltage is larger than the induced voltage generated by an adjacent secondary coil 106 which is not coaxial with the lifting coil LC.

[0034] If the first induced voltage is larger than the preset induced voltage, it is confirmed that the rod position probe 10 corresponds to the lifting coil LC.

[0035] If the first induced voltage is not larger than the preset induced voltage, it is confirmed that the rod position probe 10 does not correspond to the lifting coil LC.

[0036] Further, repeating the above-mentioned operations to complete the addressing of all control rods.

[0037] In this embodiment, a preset test current is applied to the lifting coil LC to generate a first induced magnetic field, and then the addressing of the control rod is completed according to the induced voltage generated by the secondary coil 106. The whole process does not need to move the control rod, which greatly reduces the operator's operation amount, reduces the risk of human failure, reduces the risk of communication failure, and greatly improves work efficiency and safety.

Embodiment

[0038] As shown in Fig. 4, on the basis of the above-mentioned embodiment, the nuclear power plant reactor control rod addressing method of this embodiment, before energying one lifting coil LC by the driving power, further includes:

S401, energying the primary coil 103 of the rod position probe 10 by the AC power supply, and generating a second induced magnetic field by the primary coil 103. Since the primary coil 103 and the secondary coil 106 are coaxially arranged, the secondary coil 106 may generate an induced voltage under the action of the second induced magnetic field.

S402, generating a second induced voltage by the secondary coil 106 under the action of the second induced magnetic field, recording the second induced voltages generated by all the secondary coil 106 of the rod position probe 10.

S301, energying one lifting coil LC by a driving power, and generating a first induced magnetic field by the one lifting coil LC. The energying one lifting coil LC by the driving power includes energying one lifting coil LC by the driving power and inputting with a preset test current, that is, blocking all other control rods except the control rod to be tested, and inputting with a preset test current, for example, a preset test current of 41.6A.

S302, generating a first induced voltage by the secondary coil 106 of the rod position probe 10 under the action of the first induced magnetic field. The secondary coil 106 arranged coaxially with the lifting coil LC generates a first induced voltage under the action of the first induced magnetic field. Secondary coils 106 of the other rod position probes 10 arranged on different axis from the lifting coil LC generate induced voltages under the action of the first induced magnetic field. However, the effect of the magnetic field is greatly weakened due to the different axis and the long distance between the lifting coil LC and the other rod position probes 10. Therefore, the induced voltages are much smaller than the first induced voltage.

S403, detecting the first induced voltage and the second induced voltage by the voltage detector to complete the addressing of the control rod. That is, the addressing of the control rod is completed based on the difference between the first induced voltage and the second induced voltage. The secondary coil of which the difference between the first induced voltage and the second induced voltage is much larger than other induced voltages, is the coil corresponding to the lifting coil LC. Then, it can be determined that whether the rod position probe 10 corresponds to the driving coil 30.

[0039] Further, in the nuclear power plant reactor control rod addressing method of this embodiment, after the generating the second induced voltage by the secondary coil 106 under the action of the second induced magnetic field, the method further includes:

Generating a Gray code according to the second induced voltage, and determining the corresponding rod position of the rod position probe 10.

[0040] Further, repeating the above-mentioned operations to complete the addressing of all control rods.

[0041] For example, an actual measurement test is applied for a rod bundle 1 and a rod bundle 2. During the test, when the control rods are in step 5, two adjacent control rod bundles 1 and 2 in spatial arrangement are selected. A terminal 10 and a terminal 1 of a MCP22 module are connected to a recorder. A lifting coil LC of the rod bundle 1 is energized with a large current of 41.6A. Then, the induced potential of the secondary coil 106 of the MCP22 module of rod bundle 1 changes about 500m V. Induced potential change of the secondary coil 106 of the rod bundle 2 is below 10uV. The order of magnitude difference is directly reflected on the chart, that is, the change in the rod bundle 1 is very obvious, and the change in the rod bundle 2 is substantially unchanged. As shown in Fig. 6, the upper curve represents the rod bundle 1, and the lower curve represents the rod bundle 2.

[0042] In this embodiment, the addressing of the control rod is completed by the difference between the first induced voltage and the second induced voltage. The whole process does not need to move the control rod, which greatly reduces the operator's operation amount, reduces the risk of human failure, reduces the risk of communication failure, and greatly improves work efficiency and safety.

Embodiment

[0043] As shown in Fig. 5, on the basis of the above-mentioned embodiments, in the nuclear power plant reactor control rod addressing method of this embodiment, the method further includes feedback adjustment operations of the AC power supply as below.

[0044] S501, energying a primary coil 103 of the rod position probe 10 by the alternating current (AC) power supply, and generating a second induced magnetic field by the primary coil 103 of the rod position probe 10.

[0045] S502, generating a third induced voltage by an auxiliary coil 107 of the rod position probe 10 under the action of the second induced magnetic field.

[0046] S503, the AC power supply adjusting its output current according to the third induced voltage.

[0047] In some embodiments, it was successfully applied in the overhaul of Hongyanhe Nuclear Power Plant 203. The entire addressing test was completely completed by an instrument control personnel. During the process of the addressing test, the control rod was not lifted. The total duration was about 1 hour. The effect was remarkable and fully achieved the expectation. It saves 6 hours of overhaul construction period, saves labor hours from 4 to 19 hours multiplied by 4 people, reduces the risk of control rod addressing test communication failure, and improves the unit status and core reactivity control level during the overhaul. Thereby, the safety operation level and economy of the unit benefit is improved.

[0048] The various embodiments in this specification are described in a progressive manner. Each embodiment focuses on the differences from other embodiments, and the same or similar parts between the various embodiments may be referred to each other. For the device disclosed in the embodiment, since it corresponds to the method disclosed in the embodiment, the description is relatively simple, and the relevant parts can refer to the description of the method part.

[0049] Professionals may further realize that the units and algorithm steps of the examples described in the embodiments disclosed in the present specification may be implemented by electronic hardware, computer software, or a combination of both. In order to clearly illustrate the possibilities of hardware and software, interchangeability, in the above description, the composition and operations of each example have been described generally in terms of function. Whether these functions are executed by hardware or software depends on the specific application and design constraints of the technical solution. Professionals and technicians may use different methods for each specific application to implement the described functions, but such implementation should not be considered as going beyond the scope of the present disclosure.

[0050] The operations of the method or algorithm described in combination with the embodiments disclosed herein may be implemented by hardware, a software module executed by a processor, or a combination of the two. The software module may be placed in a random-access memory (RAM), an internal memory, a read-only memory (ROM), an electrically programmable ROM, an electrically erasable programmable ROM, a register, a hard disk, a removable disk, a CD-ROM, or in any other form of storage medium known in the technical field.

[0051] The above-mentioned embodiments are only to illustrate the technical concept and features of the present disclosure, and their purpose is to enable those familiar with the art to understand the content of the present disclosure and implement them accordingly, and cannot limit the protection scope of the present disclosure. All equivalent changes and modifications made to the scope of the claims of the present disclosure shall fall within the scope of the claims of the present disclosure.

Claims

1. A nuclear power plant reactor control rod addressing device, comprising a plurality of control rods, a driving power, lifting coils LC, and a voltage detector; wherein the control rod comprises a rod position probe (10) and a rod stroke cover (20); the rod position probe (10) and the lifting coils LC are disposed on the rod stroke cover (20), and the rod position probe (10) and the lifting coils LC are coaxially disposed; the rod position probe (10) comprises a secondary coil (106);

   the driving power is respectively connected to each of the lifting coils LC; the voltage detector is respectively connected to the secondary coil (106) of each of the rod position probes (10); and the driving power is configured to selectively energize one lifting coil LC, such that the one lifting coil LC generates a first induced magnetic field, and the secondary coil (106) arranged coaxially with the one lifting coil LC generates a first induced voltage under the action of the first induced magnetic field; the voltage detector is configured to detect the first induced voltage to complete addressing of the control rod.

2. The nuclear power plant reactor control rod addressing device as claimed in claim 1, wherein the rod position probe (10) further comprises a primary coil (103) which is coaxially disposed with the secondary coil (106); and
   the primary coil (103) is configured to generate a second induced magnetic field when energized by an AC power supply such that the secondary coil (106) generates a second induced voltage under the action of the second induced magnetic field; and the voltage detector is configured to detect the first induced voltage and the second induced voltage to complete the addressing of the control rod.

3. The nuclear power plant reactor control rod addressing device as claimed in claim 2, wherein the rod position probe (10) further comprises an auxiliary coil (107); the auxiliary coil (107) is coaxially disposed with the primary coil (103); the auxiliary coil (107) is connected to the AC power supply; and
   the auxiliary coil (107) is configured to generate a third induced voltage under the action of the second induced magnetic field, and the AC power supply adjusts its output current according to the third induced voltage.

4. The nuclear power plant reactor control rod addressing device as claimed in claim 1, wherein the voltage detector is an MCP22 encoding module; and a terminal 10 of the MCP22 encoding module is connected to the secondary coil (106).

5. A nuclear power plant reactor control rod addressing method, wherein the method comprises:

   a driving power energizing one lifting coil LC, and the one lift coil LC generating a first induced magnetic field;
   a secondary coil (106) of a rod position probe (10) generating a first induced voltage under the action of the first induced magnetic field;
   completing addressing of the control rod by a voltage detector detecting the first induced voltage.

6. The method as claimed in claim 5, wherein the driving power energizing one lifting coil LC comprises: the driving power energizing the one lifting coil LC by inputting a preset test current.

7. The method as claimed in claim 5, wherein the completing addressing of the control rod by a voltage detector detecting the first induced voltage comprises:

determining whether the first induced voltage is larger than a preset induced voltage;
if the first induced voltage is larger than the preset induced voltage, confirming that the rod position probe (10) corresponds to the one lifting coil LC; and
if the first induced voltage is not greater than the preset induced voltage, confirming that the rod position probe (10) does not correspond to the one lifting coil LC.

8. The method as claimed in claim 5, wherein before the driving power energizing the one lifting coil LC, the method further comprises:

the primary coil (103) of the rod position probe (10) being energized by an AC power supply and generating a second induced magnetic field; and
the secondary coil (106) generating a second induced voltage under the action of the second induced magnetic field;
wherein the completing addressing of the control rod by a voltage detector detecting the first induced voltage comprises: completing addressing of the control rod by the voltage detector detecting the first induced voltage and the second induced voltage.

9. The method as claimed in claim 8, wherein after the secondary coil (106) generating the second induced voltage under the action of the second induced magnetic field, the method further comprises:
generating a Gray code according to the second induced voltage and determining a corresponding rod position of the rod position probe (10).

10. The method as claimed in claim 5, wherein the method further comprises:

the primary coil (103) of the rod probe (10) being energized by an AC power supply and generating a second induced magnetic field;
an auxiliary coil (107) of the rod probe (10) generating a third induced voltage under the action of the second induced magnetic field; and
the AC power supply adjusting its output current according to the third induced voltage.

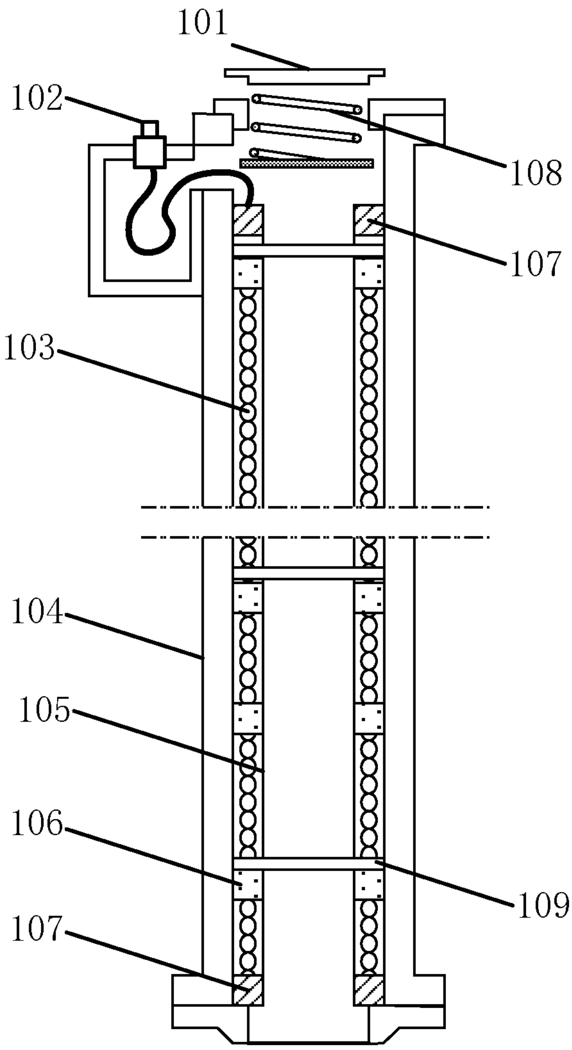

FIG. 1

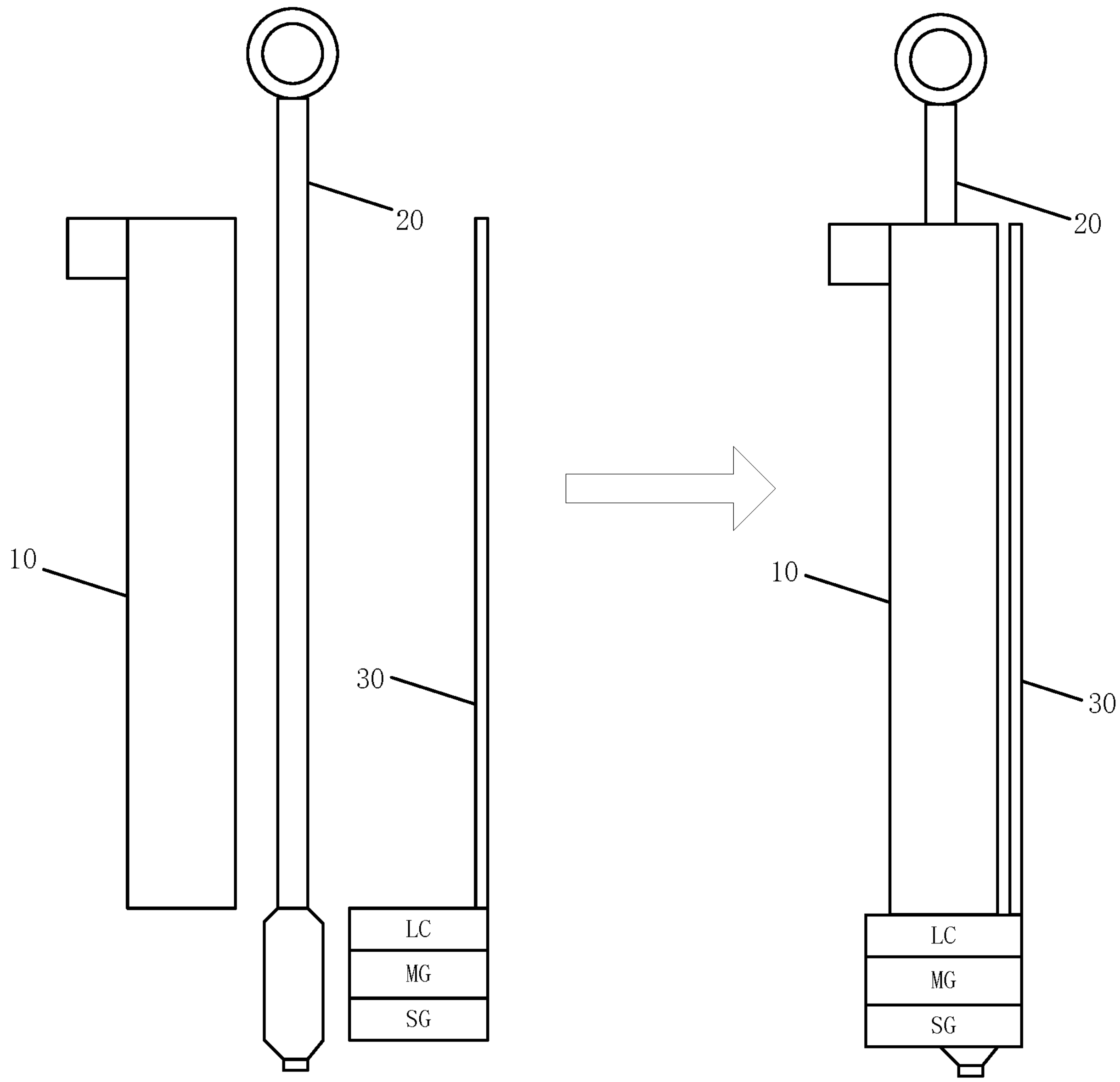

FIG. 2

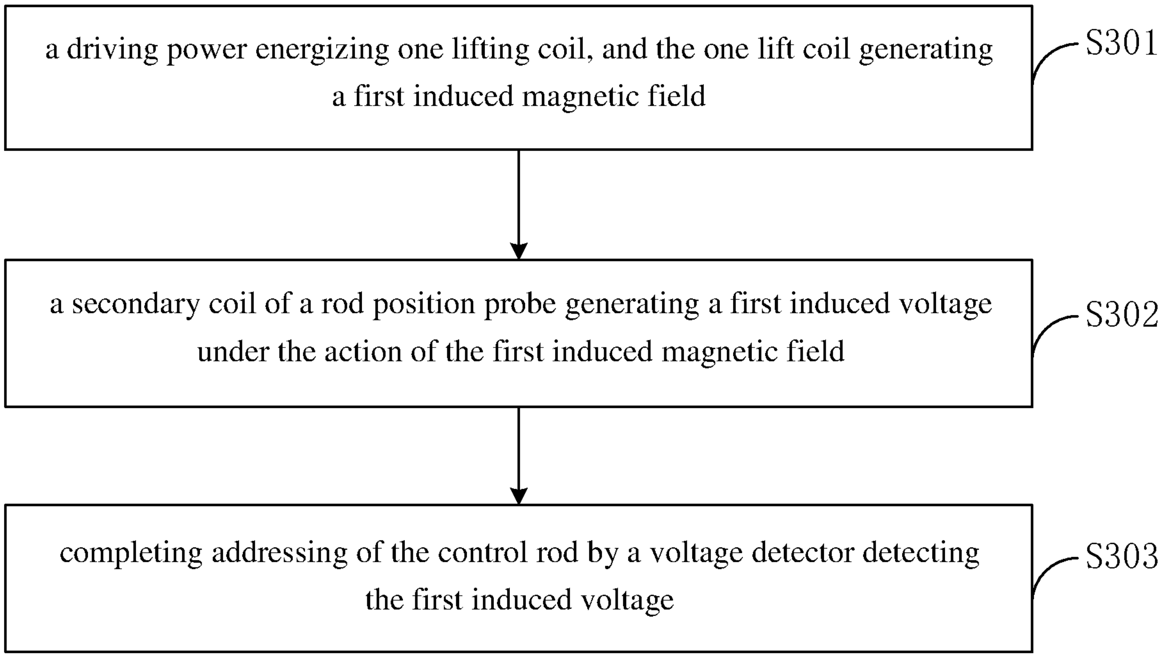
a driving power energizing one lifting coil, and the one lift coil generating a first induced magnetic field
S301
a secondary coil of a rod position probe generating a first induced voltage under the action of the first induced magnetic field
S302
completing addressing of the control rod by a voltage detector detecting the first induced voltage
S303

FIG. 3

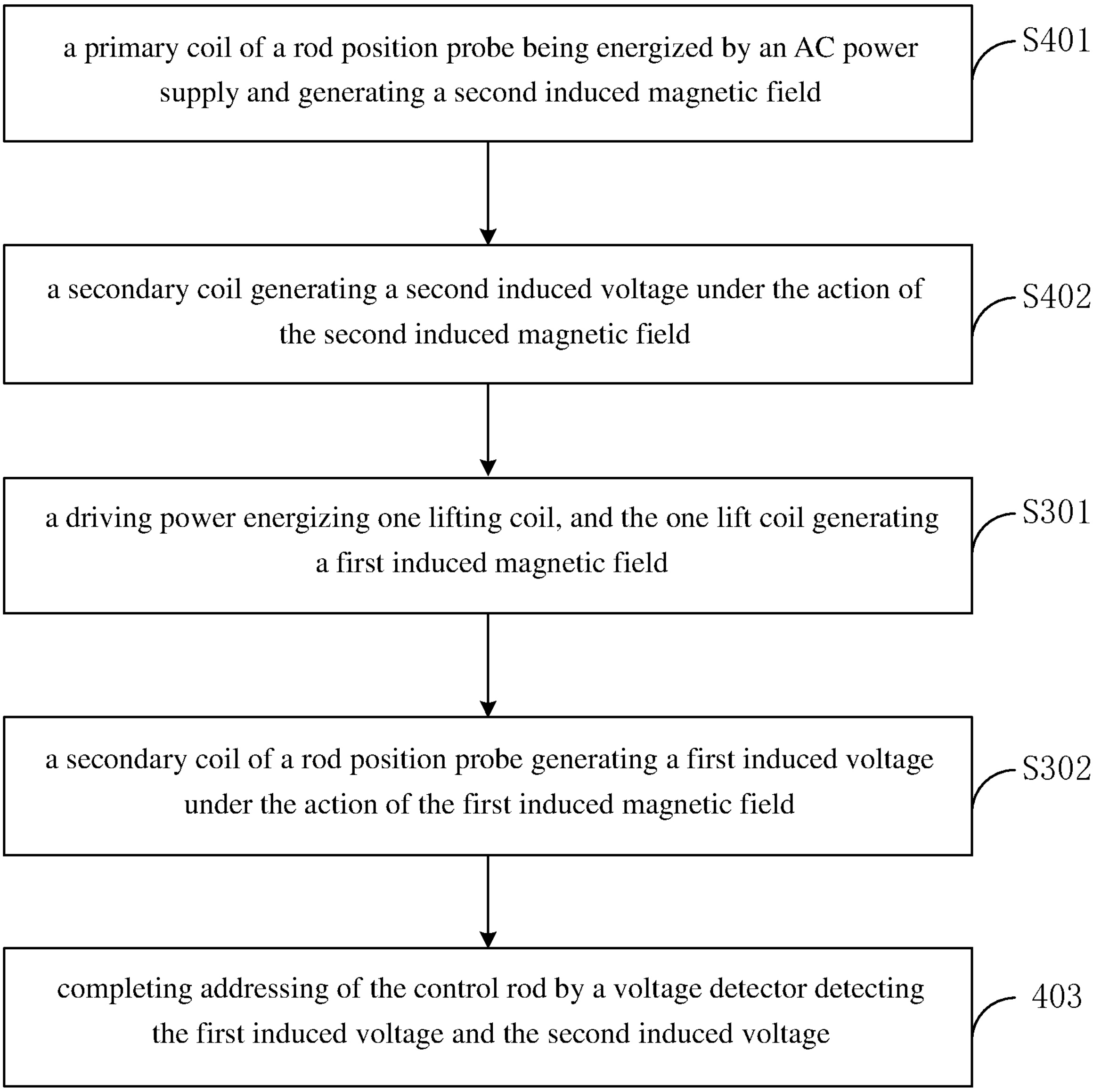
a primary coil of a rod position probe being energized by an AC power supply and generating a second induced magnetic field
S401
a secondary coil generating a second induced voltage under the action of the second induced magnetic field
S402
a driving power energizing one lifting coil, and the one lift coil generating a first induced magnetic field
S301
a secondary coil of a rod position probe generating a first induced voltage under the action of the first induced magnetic field
S302
completing addressing of the control rod by a voltage detector detecting the first induced voltage and the second induced voltage
403

FIG. 4

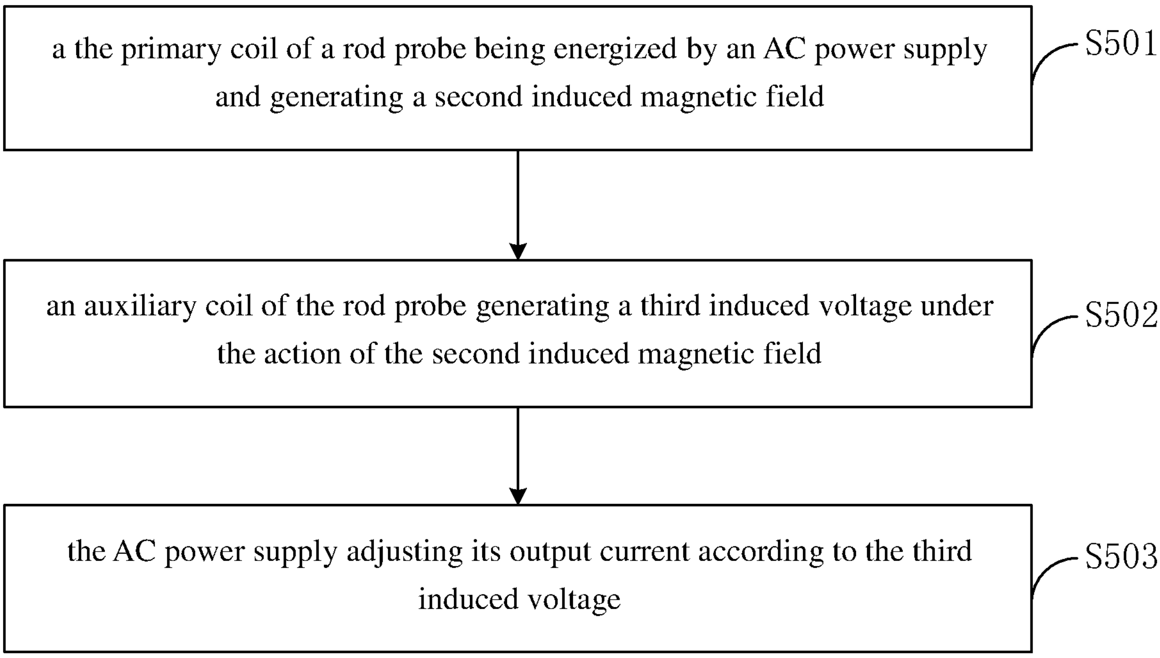
a the primary coil of a rod probe being energized by an AC power supply and generating a second induced magnetic field
S501
an auxiliary coil of the rod probe generating a third induced voltage under the action of the second induced magnetic field
S502
the AC power supply adjusting its output current according to the third induced voltage
S503

FIG. 5

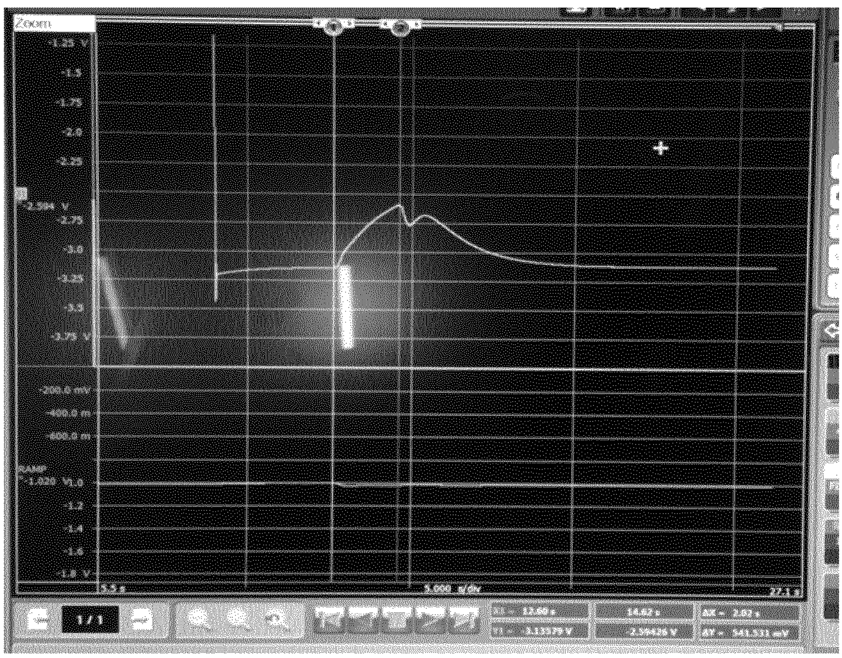

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2019/116776

A. CLASSIFICATION OF SUBJECT MATTER

G21C 17/10(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G21C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNKI, CNPAT, WPI, EPODOC: nuclear, reactor, regulate, absorb+, control, rod, address+, cable, wire, connect+, link+, joint+, channel+, test+, check+, experiment+, trial+, right+, correct+, valid+, true, wrong, false, fault+, cross+, 中广核, 核电站, 反应堆, 聚变, 中子, 棒, 寻址, 线圈, 感应, 监控, 监视, 电缆, 线缆, 电线, 插头, 通道, 线路, 联线, 连线, 连接, 通路, 准确, 正确, 交叉, 错, 误, 交错, 测试, 试验, 检查

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 109920569 A (CHINA GENERAL NUCLEAR POWER OPERATION CO., LTD. et al.) 21 June 2019 (2019-06-21) description, paragraphs [0055]-[0095], and figures 1-6	1-15
A	CN 106816191 A (JIANGSU NUCLEAR POWER CORPORATION) 09 June 2017 (2017-06-09) description, paragraphs [0018]-[0039], and figures 1-3	1-15
A	CN 106384611 A (GUANGDONG NUCLEAR POWER JOINT VENTURE et al.) 08 February 2017 (2017-02-08) entire document	1-15
A	CN 201336157 Y (CHINA TECHENERGY CO., LTD.) 28 October 2009 (2009-10-28) entire document	1-15
A	CN 105070334 A (CHINA NUCLEAR POWER ENGINEERING CO., LTD.) 18 November 2015 (2015-11-18) entire document	1-15

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 January 2020	**03 February 2020**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088** **China**	Authorized officer
Facsimile No. **(86-10)62019451**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2019/116776

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 1123775 A (HITACHI LTD.) 29 January 1999 (1999-01-29) entire document	1-15

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2019/116776

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	109920569	A	21 June 2019	None			
CN	106816191	A	09 June 2017	None			
CN	106384611	A	08 February 2017	CN	106384611	B	26 December 2017
CN	201336157	Y	28 October 2009	None			
CN	105070334	A	18 November 2015	CN	105070334	B	25 January 2019
JP	1123775	A	29 January 1999	None			

Form PCT/ISA/210 (patent family annex) (January 2015)