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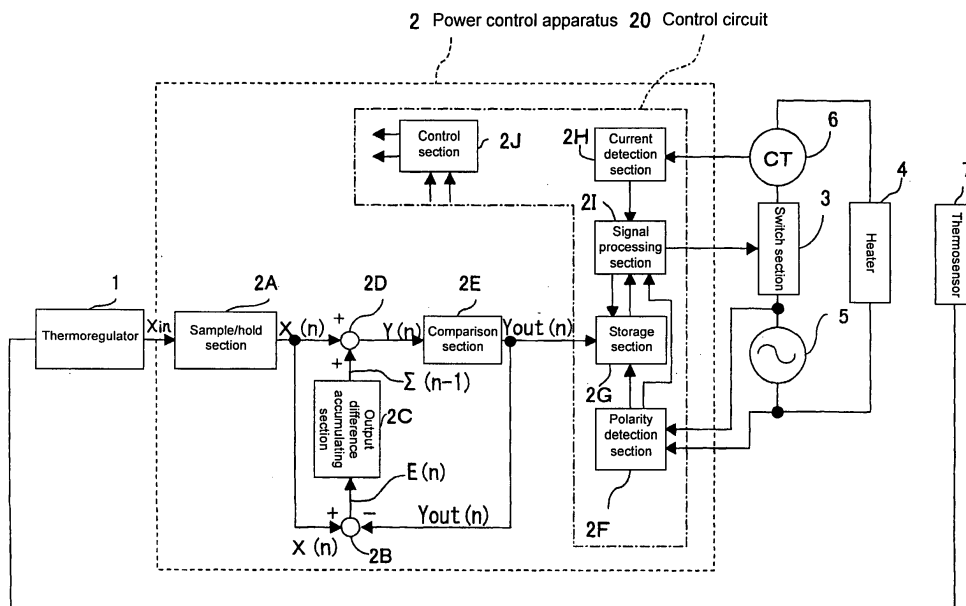
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(54) Control circuit and power control apparatus having the control circuit

(57) Providing a control circuit (20) which performs ON/OFF control of a switch section (3) connected between an AC power supply (5) and a heater (4), wherein the control circuit (20) performs control to allow the present turning ON of the switch section (3) when it is determined that an AC power supply (5) waveform (i.e.,

AC waveform) polarity at a previous turning ON at the switch section (3) is not the same as an AC waveform polarity at a present turning ON; and wherein the control circuit (20) performs control to inhibit the present turning ON of the switch section (3) when it is determined that the polarities are the same.

Fig. 1



Description

BACKGROUND OF THE INVENTION

Technical Field

[0001] The present invention relates to a control circuit for performing ON/OFF control of a switch section, which is connected between an AC power supply and a load, and to a power control apparatus using the control circuit. More particularly, the power control apparatus includes a load current detection section for detecting a load current by using a current transformer to control power to be supplied to the load.

Background Art

[0002] A current transformer (CT) has been widely and generally used for detecting a load current which is to be supplied from an AC power supply to a load, since the current transformer provides easy electrical insulation from the AC power supply, a wide range of current detection, and a suitable detection for large current.

[0003] On the other hand, in a temperature control system such as a heater, there is provided a power control apparatus in which a switch section is connected between an AC power supply and the heater, and the switch section is turned ON/OFF at hourly base, thereby controlling power to be applied to the heater. Such power control apparatus includes, for example, a cycle control system which detects an AC power supply voltage by zero cross detection and performs ON/OFF control of the switch section every half cycle of the AC power supply or a phase control system which performs ON/OFF control of the switch section by controlling a phase angle of the AC power supply (refer to Japanese Unexamined Patent Application Publication No. 2001-265446).

[0004] In the above-mentioned power control apparatus, a current transformer is used to detect a wire break in the heater. Many power control apparatuses are provided with a function which outputs the heater wire break alarm as it is considered that the heater has a wire break when the current detected by the current transformer is less than a predetermined value. The current transformer is made of a toroidal core and a detection coil wound thereto, and is penetrated through by a wire, through which flows a current to be measured, so as to generate an induction electromotive force between the current flowing through the wire and the detection coil, thereby detecting an alternating current by detecting the magnitude of the induction electromotive force. In addition, the ratio between the alternating current to be measured and the alternating current outputted from the current transformer is determined by a turn ratio (a transformation ratio) of the detection coil.

[0005] However, as described above, the current transformer can detect only an alternating current in

principle, because the current is detected by means of the induction electromotive force between two coils. Consequently, in the case where an alternating current flows through the heater, for example, in the case where performs ON/OFF control with a sufficiently long interval between ON and OFF, the heater current can be detected with high accuracy. Whereas for use in the case where performs ON/OFF control for each half cycle of an alternating current, the alternating current sometimes continues to flow in the same direction. The heater current in this case is a current which ripple is superimposed on a direct current, and therefore the electromotive force induced at the current transformer coil depends on only changed portion (the ripple portion in this case). Consequently, the detection current becomes less than the original detection current which is determined by the current to be detected and the transformation ratio, and therefore detection accuracy is significantly degraded.

DISCLOSURE OF THE INVENTION

[0006] It is an object of the present invention to provide a control circuit which, even if a current transformer is used in such an application where performs ON/OFF control for each half cycle of an alternating current, enables to detect a wire break of load such as a heater with high accuracy and to increase detection speed and its accuracy; and to provide a power control apparatus using the control circuit, which allows a control with high accuracy and high responsiveness.

[0007] In order to solve the above problems, the present invention is configured as follows. A control circuit according to a first aspect of the present invention, is for performing ON/OFF control of a switch section connected between an AC power supply and a load; wherein the control circuit determines whether or not an AC power supply waveform (i.e., AC waveform) polarity at a previous turning ON at the switch section is the same as an AC waveform polarity at a present turning ON; wherein the control circuit performs control to allow the present turning ON of the switch section when it is determined that the polarities are not the same; and wherein the control circuit performs control to inhibit the present turning ON of the switch section when it is determined that the polarities are the same. Preferably, in order to achieve the above-mentioned permission and inhibition process, the present invention may be configured to comprise: a polarity detection section for detecting the AC waveform polarity; a storage section for storing an AC waveform polarity at the time the switch section is turned ON, from a detection output of the polarity detection section; and a signal processing section for determining whether or not the AC waveform polarity at the previous turning ON at the switch section is the same as the AC waveform polarity at the present turning ON of the switch section, the polarities being stored by the storage section, for allowing the present turning ON of

the switch section when it is determined that the AC waveform polarity at the present turning ON of the switch section is not the same as the AC waveform polarity at the previous turned ON, and for inhibiting the present turning ON of the switch section when it is determined that the AC waveform polarity at the present turning ON of the switch section is the same as the AC waveform polarity at the previous turning ON.

[0008] According to the first aspect of the present invention, in the power control in which a power from an AC power supply is applied to, for example, a heater being the load by ON/OFF control of the switch section, when a wire break etc. of the heater is detected by a current transformer, the current transformer can detect a load current correctly by the ON-OFF control of the switch section. That is, the current transformer is made of a toroidal core and a detection coil wound thereto. Therefore, in the case where the current transformer is incorporated in a wiring between the heater and the AC power supply, if a previous half cycle of an alternating current and a present half cycle are the same polarities (homopolarity), the alternating current to be detected becomes smaller than the actual load current and detection accuracy significantly degrades. Whereas, according to the present invention, the previous half cycle of the alternating current and the present half cycle are opposite polarities, and therefore the current is an alternating current and the current to be detected corresponds to the actual load current and detection accuracy is significantly improved.

[0009] Specifically, according to the present invention, the following effects can be obtained: correlation (a transformation ratio) between the current transformer output and the actual load current is stabilized; current detection accuracy is improved; in addition, detection from a first half cycle after powered on of the AC power supply for the load can be possible; responsiveness in detection of a wire break of the load such as a heater, and in detection of over-current or the like, are improved; and further, in high accuracy cycle control disclosed in Japanese Unexamined Patent Application Publication No.2001-265446, current detection using the current transformer can be possible.

[0010] As a preferable embodiment of the above-mentioned control circuit, the present invention may be configured to comprise: a load current detection section for detecting a load current from a current transformer output, wherein the signal processing section detects the presence or absence of a wire break of the load based on an output of the load current detection section, and negates the output of the load current detection section when the AC waveform polarity at the previous turning ON of the switch section is uncertain. According to this configuration, although homopolarity might continue in the case where a power control apparatus is powered on or a load's AC power supply fails; in this case, the detected current is not used for detection processing of a wire break, and therefore error detection of the pres-

ence or absence of a wire break of the load can be avoided.

[0011] A control circuit according to a second aspect of the present invention, is for performing ON/OFF control of a switch section connected between an AC power supply and a load; wherein the control circuit determines whether or not parity of the number of AC polarity alternations from a previous given point in time to a turning ON point at the switch section is the same as parity of the number of polarity alternations at a present turning ON; wherein the control circuit performs control to allow the present turning ON of the switch section when it is determined that the parities are not the same; and wherein the control circuit performs control to inhibit the present turning ON of the switch section when it is determined that the parities are the same. Preferably, in order to achieve the above-mentioned permission and inhibition process, the present invention may be configured to comprise: a count detection section for counting the number of AC polarity alternations from the given point in time to turning ON point of the switch section, and for storing the parity of the number of polarity alternations; and a signal processing section for obtaining the parity of the number of polarity alternations at the previous turning ON of the switch section from the count detection section, for determining whether or not the parity of the number of polarity alternations at the previous turning ON is the same as the parity of the number of polarity alternations at the present turning ON, for allowing the present turning ON of the switch section when it is determined that the parities are not the same, and for inhibiting the present turning ON of the switch section when it is determined that the parities are the same.

[0012] According to a second aspect of the present invention, in the power control in which a power from an AC power supply is applied to, for example, a heater being the load by ON/OFF control of the switch section, when a wire break etc. of the heater is detected by a current transformer, the current transformer can detect a load current correctly by the ON-OFF control of the switch section. That is, the current transformer is made of a toroidal core and a detection coil wound thereto. Therefore, in the case where the current transformer is incorporated in a wiring between the heater and the AC power supply, if half cycles of parity of the alternating current are the same polarities, the alternating current to be detected becomes smaller than the actual load current, thus detection accuracy significantly degrades. Whereas, according to the present invention, parity of a half cycle at the previous turning ON and a half cycle at the present turning ON of the alternating current are different, and therefore the current is an alternating current and the current to be detected corresponds to the actual load current thus detection accuracy is significantly improved.

[0013] As a preferable embodiment of the above-mentioned control circuit, the present invention may be

configured to comprise: a load current detection section for detecting a load current from a current transformer output, wherein the signal processing section detects the presence or absence of a wire break of the load based on an output of the load current detection section, and negates the output of the load current detection section when the parity of the number of polarity alternations at the previous turning ON of the switch section, the parity being counted from the given point in time, is uncertain. According to this configuration, although homopolarity might continue in the case where a power control apparatus is powered on or a load's AC power supply fails; in this case, the detected current is not used for detection processing of a wire break, and therefore error detection of the presence or absence of a wire break of the load can be avoided.

[0014] A power control apparatus according to the present invention is for outputting an output power command value at predetermined cycles more than a half cycle of an AC power supply in response to an input power command value, and for performing ON/OFF control of a switch section connected between the AC power supply and a load, in accordance with the output power command value to control power supply to be supplied to the load, the power control apparatus comprising: an output difference accumulating section for accumulating the difference between an output power command value and an input power command value; an addition section for adding an input power command value and an output difference accumulated value accumulated at the output difference accumulating section; a comparison section for comparing a threshold with an added value which the addition section added, for outputting an output power command value as 100% when the added value is more than the threshold, and for outputting an output power command value as 0% when the added value is less than the threshold as a result of the comparison; and a control circuit according to the first aspect or the second aspect of the present invention.

[0015] According to the present invention, there can be provided a control circuit which can use a current detected by a current transformer by constantly flowing an alternating current through the current transformer, and in a power control apparatus using the control circuit, control of supplying power to the load can be performed with high accuracy and high responsiveness.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1 shows a schematic diagram showing a temperature control system according to an embodiment of the present invention.

Fig. 2 shows a flow chart showing an operation example of the embodiment of Fig. 1.

Fig. 3 shows a detail flow chart showing Step ST10

of Fig. 2.

Fig. 4 shows a chart for explaining effect of a background art.

Fig. 5 shows a chart for explaining effect of the present invention.

Fig. 6 shows a chart for explaining effect of a background art.

Fig. 7 shows a chart for explaining effect of the present invention.

Fig. 8 shows a schematic diagram showing a temperature control system according to another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] Next, a power control apparatus having a control circuit according to embodiments of the present invention will be described in detail with reference to the drawings. It is to be noted that the following embodiments are examples, and thus do not limit the scope of the present invention. Fig. 1 shows a block diagram showing a schematic configuration of a temperature control system including a power control system. The temperature control system includes a thermoregulator 1, a power control apparatus 2, a switch section 3 composed of a solid state relay (referred to as SSR) or the like, a heater 4 being a load, an AC power supply 5, a current transformer 6, and a thermosensor 7. The switch section 3 is connected between the heater 4 and the AC power supply 5. The heater 4 is placed inside a heating furnace not shown, the thermosensor 7 detects an internal temperature of the heating furnace, and outputs the detected output to the thermoregulator 1. The current transformer 6 is placed in a wiring (conductive wire) for constituting a closed circuit by the switch section 3, the heater 4, and the AC power supply 5 so as to detect a heater current being a load current flowing through the conductive wire.

[0018] In the temperature control system described above, the power control apparatus 2 includes a sample/hold section 2A for holding an input power command value X_{in} from the thermoregulator 1 during a half cycle; an output difference arithmetic section 2B for calculating an output difference $E(n)$ between an input power command value $X(n)$ after the sample/hold and the actual output value $Y_{out}(n)$; an output difference accumulating section 2C for accumulating the output difference $E(n)$ calculated by the output difference arithmetic section 2B; an addition section (correction section) 2D for adding the input power command value $X(n)$ and an output difference accumulated value $\Sigma(n-1)$; and a comparison section 2E for comparing an added output value $Y(n)$ of the addition section 2D with a threshold S as a reference value, and for outputting an output power command value $Y_{out}(n)$ of 100% or 0% in response to the result of the comparison. The comparison section 2E outputs the output power command value $Y_{out}(n)$ of 100% or 0%.

[0019] The power control apparatus 2 also includes a polarity detection section 2F for detecting a waveform (AC waveform) polarity of the AC power supply 5; a storage section 2G for storing an AC waveform polarity at the time at least the switch section 3 is turned ON, from AC waveform polarities detected by the polarity detection section 2F; a current detection section 2H for detecting a heater current from an output of the current transformer 6; and a signal processing section 2I for performing a signal processing, such as detection of a wire break of the heater from the detection output of the current detection section 2H. The signal processing section 2I also determines whether or not the previous AC waveform polarity which the storage section 2G stores is the same as the AC waveform polarity at the present turning ON of the switch section 3 from the polarity detection section 2F; allows the present turning ON of the switch section 3 when it is determined that the AC waveform polarity at the present turning ON of the switch section 3 is not the same as the AC waveform polarity at the previous turned ON; and inhibits the present turning ON of the switch section 3 when it is determined that the AC waveform polarity at the present turning ON of the switch section 3 is the same as the AC waveform polarity at the previous turning ON. The signal processing section 2I negates the output of the current detection section 2H when the AC waveform polarity at the previous turning ON of the switch section 3 is uncertain. The power control apparatus 2 includes a control section 2J which performs the above-mentioned respective controls. The respective sections may be composed of a microcomputer. For example, a microcomputer includes a central processing unit (referred to as CPU) for carrying out a whole control, a program memory in which a program executing the CPU operation is stored, a work memory for providing a work area of the CPU, and buses for connecting these parts each other. Each of the above-mentioned respective sections can be functionally configured by the aforementioned microcomputer. Needless to say, the above-mentioned respective sections are not limited to configuration of software by microcomputer, but may be configured by hardware. For example, the polarity detection section 2F for detecting a waveform of the AC power supply 5 may be constituted by known one such configuration, in which a non-inversion input section and an inversion input section of a comparator are connected to the AC power supply 5, thus a pulse output is performed when the polarity of the AC power supply is positive; but a pulse output is inhibited when the polarity is negative. There is another configuration, which is constituted by a luminescent type bidirectional thyristor being connected to the AC power supply in parallel and a light sensitive transistor operating in response to the light output of the bidirectional thyristor, thus a pulse output from a collector of the light sensitive transistor is performed when the polarity of the AC power supply is positive; but a pulse output is inhibited when the polarity is negative.

[0020] The control circuit 20 is constituted by the above-described polarity detection section 2F, storage section 2G, signal processing section 2I and control section 2J, whereby when it is determined that AC waveform polarity at a previous turning ON at the switch section 3 is not the same as an AC waveform polarity at a present turning ON, the control circuit performs control to allow the present turning ON of the switch section 3; and when it is determined that the polarities are the same, the control circuit performs control to inhibit the present turning ON of the switch section 3. Further, the control section 2J has a function which makes each section perform operations of flow charts shown in Fig. 2 and Fig. 3. However, the control section 2J is not always to be provided in the control circuit 20, if the signal processing section 2I has the function which makes each section perform operations of flow charts shown in Fig. 2 and Fig. 3.

[0021] In addition, memory content of the storage section 2G may update its memory content by the signal processing section 2I or by the storage section 2G itself. For example, when the storage section 2G memorizes a detection output (a first polarity) of the AC waveform polarity of a half cycle at the present turning ON of the switch section 3 from the polarity detection section 2F, a detection output (a second polarity) of the AC waveform polarity of a subsequent half cycle from the polarity detection section 2F is inputted. Then, when the signal processing section 2I uses the first polarity already stored in the storage section 2G as the previous polarity, the memory of the storage section 2G is updated from the first polarity to the subsequent second polarity so as to utilize the second polarity as the previous polarity. Alternatively, the storage section 2G updates polarity data in response to the use of the polarity of the signal processing section 2I. The signal processing section 2I may directly input the present polarity data from the polarity detection section 2F. The AC waveform polarity memorized at the storage section 2G is memorized in flag style. That is, the previous polarity denotes the previous polarity flag A, flag +1(positive) denotes that the power supply polarity at the previous half cycle output is positive, flag -1(negative) denotes that the power supply polarity at the previous half cycle output is negative, and flag "0" denotes that the previous output is absent or uncertain. The present polarity denotes the present polarity flag B, flag +1(positive) denotes that the power supply polarity at the present half cycle output is positive, flag -1(negative) denotes that the power supply polarity at the present half cycle output is negative, and flag "0" denotes that the present output is absent or uncertain.

[0022] In addition, the control circuit 20 performs the following flag update control on the setting of the polarity flags A and B to be stored in the storage section 2G. That is, as the initial-value, the polarity flag is set to 0. Then, as (Condition 1), the present turning ON of the switch section 3 is allowed in the case of the polarity=0;

the polarity flag is set to +1 when the power supply polarity at the present turning ON is positive; and the polarity flag is set to -1 when the power supply polarity at the present turning ON is negative. As (Condition 2), the present turning ON is allowed when the polarity flag is +1 and the power supply polarity at the present turning ON is negative; the polarity flag is set to -1 by subtracting 2 from the polarity flag; but the present turning ON is inhibited when the power supply polarity at the present turning ON is positive. As (Condition 3), the present turning ON is allowed when the polarity flag is -1 and the power supply polarity at the present turning ON is positive; the polarity flag is set to +1 by adding 2 to the polarity flag; but the present turning ON is inhibited when the power supply polarity at the present turning ON is negative. Further, a current detection error is outputted unless when the polarity flags are -1, 0, and +1.

[0023] An operation of a temperature control system having the above-described configuration will be described with reference to Fig. 2 and Fig. 3. Fig. 2 shows a basic flow chart showing the temperature control system, and Fig. 3 shows a detail flow chart showing an output permission/rejection determination subroutine of Fig. 2. At the start of the operation, the control section 2J constituted by CPU performs initialization first (Step ST1). As this initialization, a setting of threshold S of the comparison section 2E (Step ST2) and a clear of variable n of a self-contained register of the control section 2J (Step ST3) are executed. As a setting of a parameter initial-value, a clear (0%) of an accumulated difference $\Sigma(n)$ of the output difference accumulating section 2C and a setting of 0 (zero) of the previous polarity flag A (Step ST4) etc. are executed.

[0024] Subsequently to the above-mentioned initialization, a variable n of the self-contained register of the control section 2J is incremented by 1, ($n \leftarrow n+1$) (Step ST5). Then, an input power command value X(n) is fetched to the addition section 2D from the thermoregulator 1 via the sample/hold section 2A (Step ST6). Further, as described above, the heater 4 is placed in a heating furnace, and a material to be heated which is heated by the heater 4 is arranged inside the heating furnace. In order to properly heat the materials to be heated, the thermoregulator 1 performs control of driving amount of the heater 4 from an output of the thermosensor 7 to adjust temperature inside the heating furnace. Therefore, the thermoregulator 1 finds an input power command value Xin from the output of the thermosensor 7 to output it to the power control apparatus 2. An output difference accumulated value $\Sigma(n-1)$ up to the previous time is simultaneously fetched to the addition section 2D from the output difference accumulating section 2C. In the addition section 2D, the present input command value X(n) and the output difference accumulated value $\Sigma(n-1)$ up to the previous time are added, and this added value is outputted to the comparison section 2E as a correction output value Y(n) (Step ST7).

[0025] Next, an output threshold determination

processing is performed (ST8). The output threshold determination processing compares the correction output value Y(n) with a threshold S(50%) at the comparison section 2E, and determines whether or not the correction output value Y(n) exceeds the threshold S(50%). Subsequently, it is determined whether or not an output power command is outputted (ST9). When the correction output value Y(n) is more than the threshold S(50%), an output power command value Yout(n) is determined as 100% (an output power command is present in this case). On the other hand, when the correction output value Y(n) is less than the threshold S(50%), the output power command value Yout(n) is determined as 0(%) (an output power command is absent in this case). Further, such threshold S is one example, and it may be accordingly changed.

[0026] In the above-mentioned ST9, when it is determined that "an output power command is present", an output permission/rejection determination is executed (ST10). The output permission/rejection determination follows a flow chart of Fig. 2(to be described later). On the other hand, when it is determined that "an output power command is absent", a deviation between the present input power command value X(n) and the actually outputted output power command value Yout(n), i. e., an output difference $E(n) \leftarrow X(n) - Yout(n)$ is operated at the arithmetic section 2B (Step ST11); and at the output difference accumulating section 2C, the present output difference E(n) is added to the output difference accumulated value $\Sigma(n-1)$ up to the previous time to update the output difference accumulated value from $\Sigma(n-1)$ to $\Sigma(n)$ (Step ST12). Getting back to Step ST5 after the completion of the above-described half cycle processing, variable n is incremented by 1 to execute the next half cycle processing. Processing from Step ST5 to Step ST12 is repeated over the control cycle; in the next cycle, variable n and $\Sigma(n)$ are updated again and the similar processing is repeated.

[0027] The cycle control described above is proposed by Japanese Unexamined Patent Application Publication No. 2001-265446, and No. 2002-325428 etc., detail description based on specific values can be referred to idem, and their description will not be repeated.

[0028] Next, the output permission/rejection determination Step ST10 will be described with reference to Fig. 3.

[0029] In Step SUB1, it is determined whether or not the previous polarity flag A is 0. When it is determined that the previous polarity flag A is 0, a processing is shifted to between Step SUB5 and Step SUB 8. When it is determined that the previous polarity flag A is not 0, a processing is shifted to Step SUB2. In Step SUB2, it is determined whether or not the previous polarity flag A is +1(positive). When it is determined that the previous polarity flag A is +1(positive), a processing is shifted to between Step SUB10 and Step SUB13. When it is determined that the previous polarity flag A is not +1(positive), a processing is shifted to Step SUB3. In Step

SUB3, it is determined whether or not the previous polarity flag A is -1(negative). When it is determined that the previous polarity flag A is -1(negative), a processing is shifted to between Step SUB14 and Step SUB17. When it is determined that the previous polarity flag A is not -1(negative), a processing is shifted to Step SUB4 and an output of the current transformer CT is fetched.

[0030] First, in between Step SUB5 and Step SUB8 when it is determined that the previous polarity flag A is 0 at Step SUB1, first at Step SUB 5, it is determined whether or not the present polarity flag B is +1(positive). When it is determined that the present polarity flag B is not +1(positive) at Step SUB5, the previous polarity flag A is set to -1(negative) at Step SUB6; and when it is determined the present polarity flag B is +1(positive), the previous polarity flag A is set to +1(positive) at Step SUB7. In the next Step SUB8, in both Step SUB6 and Step SUB7, it is allowed to output an output power command value Yout(n) from the comparison section 2E to the switch section 3. In this regard, since the previous polarity flag A is 0 in Step SUB 1 and it is uncertain whether the previous polarity flag A is +1(positive) or -1 (negative), it is uncertain whether or not the previous polarity flag A differs from the present polarity flag B in Step SUB5 to Step SUB7, consequently an output of the current transformer CT is not fetched at Step SUB9. Then, in preparation for the next polarity determination, the present polarity flag B is set to -1(negative) at Step SUB6 or +1(positive) at Step SUB7 as the previous polarity flag A.

[0031] In Step SUB 2, when it is determined the previous polarity flag A is +1(positive), a processing is shifted to between Step SUB10 and Step SUB13. In Step SUB10, it is determined whether or not the present polarity B is +1(positive). When it is determined that the present polarity flag B is not +1(positive), a processing is shifted to Step SUB11 to update the previous polarity flag A to -1(negative); and then in Step SUB12, it is allowed to output an output power command value Yout (n) from the comparison section 2E to the switch section 3. It is because the previous polarity flag A differs from the present polarity flag B. When it is determined that the present polarity flag B is +1(positive), which is the same as the polarity of the previous polarity flag A; and therefore in Step SUB13, it is inhibited to output an output power command value Yout(n) from the comparison section 2E to the switch section 3. The output power command value Yout(n) at this time is 0%, because the previous polarity flag A is the same as the present polarity flag B.

[0032] In Step SUB3, when it is determined that the previous polarity flag A is -1(negative), it is determined whether or not the present polarity flag B is -1(negative) at Step SUB14. In Step SUB14, when it is determined that the present polarity flag B is not -1(negative), in Step SUB15, the previous polarity flag A is updated to +1(positive); and then in Step SUB16, it is allowed to output an output power command value Yout(n) from the

comparison section 2E to the switch section 3. It is because the previous polarity flag A differs from the present polarity flag B. In Step SUB14, when it is determined that the present polarity flag B is -1(negative), it is inhibited to output an output power command value Yout(n) from the comparison section 2E to the switch section 3 in Step SUB17. It is because the previous polarity flag A is the same as the present polarity flag B. In the above described Steps SUB12, SUB13, SUB16, and SUB17, an output of the current transformer CT is fetched in Step SUB4.

[0033] As described above, when there is an output command at Step ST9 in the flow chart of Fig. 2, the above-described output permission/rejection determination is executed based on the flow chart of Fig. 3 which is a detail flow chart of Step ST10. An output is allowed when the previous polarity flag A differs from the present polarity flag B. Next, with reference of Fig. 4 to Fig. 7, difference of the output of the current transformer 6 between the following cases will be described: one is such a case, as the present invention, that it is allowed to output to the switch section 3 only when the previous polarity flag A differs from the present polarity flag B; the other case is, as the conventional one, that it is allowed to output to the switch section 3 even if when the previous polarity flag A is the same as the present polarity flag B.

[0034] Fig. 4 shows a chart of an example of a background art at an input command value X(n) (a control amount) of 25%, and Fig. 5 shows a chart of this embodiment according to the present invention at an input command value X(n) (a control amount) of 25%. Both Fig. 4A and Fig. 5A show a waveform (filled part) of an actual heater current(load current), and both Fig. 4B and Fig. 5B show an output waveform of the current transformer 6. In this regard, the entire dashed lines denote an AC waveform of the AC power supply 5, and the filled parts denote output waveforms of the heater current and the current transformer 6. As seen in the examples of Fig. 4 and Fig. 5, the output level of the current transformer 6 of the background art becomes smaller than the actual heater current and the output appears even during the period which the actual current is not flown. Whereas, the output level of the current transformer 6 of this embodiment corresponds to the actual heater current and no output of the current transformer 6 appears during the period which the heater current is not flown. This implies that the output of the current transformer 6 of this embodiment corresponds to the actual heater current.

[0035] Fig. 6 shows a chart of an example of a background art at an input command value X(n) (a control amount) of 50%, and Fig. 7 shows a chart of this embodiment according to the present invention at an input command value X(n) (a control amount) of 50%. Both Fig. 6A and Fig. 7A show a waveform (filled part) of an actual heater current, and both Fig. 6B and Fig. 7B show an output waveform of the current transformer 6. In this

regard, the entire dashed lines denote AC waveforms of the AC power supply 5, and the filled parts denote output waveforms of the heater current and the current transformer 6. As seen in the examples of Fig. 6 and Fig. 7, the output level of the current transformer 6 of the background art becomes smaller than the actual heater current and the output appears even during the period which the actual current is not flown. Whereas, the output of the current transformer 6 of this embodiment corresponds to the actual heater current and no output of the current transformer 6 appears during the period which the heater current is not flown. This implies that the output of the current transformer 6 of this embodiment corresponds to the actual heater current.

[0036] In addition, regarding the control amount except the above-mention, for example, 4.3%, 7.7%, 14%, 33%, the inventors have confirmed that the output of the current transformer 6 corresponds to the actual heater current and the output is not appeared on the negative half cycle side.

[0037] Accordingly, the power control apparatus 2 of this embodiment performs ON/OFF control of the switch section 3 based on an input command value X(n), to a closed circuit in which the switch section 3 is connected between the heater 4 and the AC power supply 5. In the power control apparatus 2, the output of the current transformer 6 is fetched to the current detection section 2H, and the signal processing section 2I detects the presence or absence of a wire break based on the detected output of the current detection section 2H, whereby treatment of a wire break of the heater can be correctly performed.

[Another embodiment]

[0038] Another embodiment according to the present invention will be described with reference to Fig. 8. In Fig. 8, the same reference numerals are given to those identical or equivalent to the portions shown in Fig. 1, and description of the portions of the same reference numerals will not be repeated. It is characterized in that in the control circuit 20 of Fig. 1 of this embodiment, the polarity detection section 2F and the storage section 2G are replaced by a zero cross detection section 2K and a count detection section 2L respectively, and processing content of the signal processing section 2I is also changed in response to the replaced sections. The zero cross detection section 2K detects zero cross of a voltage of the AC power supply 5; and the count detection section 2L counts the number of AC polarity alternations from the given point in time to turning ON point of the switch section 3 by using zero cross detection obtained at the zero cross detection section 2K, and stores parity of the number of polarity alternations. The signal processing section 2I performs signal processing such as detection of the presence or absence of a wire break of a heater based on an output of a current detection section 2H; obtains the parity (odd number or even

number in the number of polarity alternations) of the number of polarity alternations at the previous time of the switch section 3 from the count detection section 2L and the parity of the number of polarity alternations at the present turning ON; allows the present turning ON of the switch section 3 when the parities of the number of polarity alternations at the previous turning ON and the present turning ON are not the same; and inhibits the present turning ON of the switch section 3 when the parities of the number of polarity alternations at the previous turning ON and the present turning ON are the same.

[0039] In this another embodiment, the control circuit 20 includes zero cross detection section 2K, the count detection section 2L, and the signal processing section 2I, by those which the control circuit 20 performs control to allow the present turning ON of the switch section 3 when the parity of the number of AC polarity alternations from a given point in time to the previous turning ON point at the switch section 3 is not the same as the parity of the number of polarity alternations at the present turning ON; and inhibits the present turning ON of the switch section 3 when the parities are the same.

[0040] In this control circuit 20, the following flag update control on the setting of the polarity flags A and B to be stored in the count detection section 2L is also performed. That is, as the initial-value, the polarity flag is set to 0. Then, as (Condition 1), the present turning ON of the switch section 3 is allowed in the case of the parity=0; the polarity flag is set to +1 when the parity of the number of power supply polarity alternations at the present turning ON is odd number; and the polarity flag is set to -1 when the parity of the number of power supply polarity alternations at the present turning ON is even number. As (Condition 2), the present turning ON is allowed when the polarity flag is +1 and the parity of the number of power supply polarity alternations at the present turning ON is even number; the polarity flag is set to -1 by subtracting 2 from the polarity flag; and the present turning ON is inhibited when the parity of the number of power supply polarity alternations at the present turning ON is odd number. As (Condition 3), the present turning ON is allowed when the polarity flag is -1 and the parity of the number of power supply polarity alternations at the present turning ON is odd number; the polarity flag is set to +1 by adding 2 to the polarity flag; and the present turning ON is inhibited when the parity of the number of power supply polarity alternations at the present turning ON is even number. Further, a current detection error is outputted unless when the polarity flags are -1, 0, and +1.

[0041] An operation will be described with reference with the flow chart of Fig. 3. In this regards, in the above-described embodiment, the previous polarity flag A and the present polarity flag B denote the polarity of the power supply half cycle at turning ON of the switch section 3. However, in this embodiment, the previous polarity flag A is set to +1(positive) when the parity is odd

number with respect to the parity of the number of polarity alternations from a given point in time to a previous turning ON point at the switch section 3; and the previous polarity flag A is set to -1(negative) when the parity is even number. The present polarity flag B is set to +1 (positive) when the parity is odd number with respect to the parity of the number of polarity alternations from a given point in time to a present turning ON point at the switch section 3; and the present polarity flag B is set to -1(negative) when the parity is even number. According to such definition, the flow chart of Fig. 3 based on the parity of the number of polarity alternations is similar to that of the above-described embodiment, and therefore their detail description will not be repeated. In brief, the previous polarity flag A is 0 and uncertain in Steps SUB6 and SUB7, an output of the current transformer 6 is not fetched though output is allowed. Further, since the previous polarity flag A is +1(positive) and the present polarity flag B is -1(negative) in Step SUB11, an output is allowed in Step SUB12. Although the previous polarity flag A is +1(positive) in Step SUB13, the present polarity flag B is also +1(positive), thus an output is inhibited. In addition, the previous polarity flag A is -1(negative) in Step SUB15 and the present polarity flag B is +1(positive), thus an output is allowed in Step SUB16. Although the previous polarity flag A is -1(negative) in Step SUB17, the present polarity flag B is also -1(negative), thus an output is inhibited.

[0042] Further, in this another embodiment, the signal processing section 2I negates an output of the current detection section 2H when the parity of the number of polarity alternations at the previous turning ON of the switch section 3, the parity being counted from the given point in time, is uncertain.

[0043] Accordingly, the power control apparatus 2 of this another embodiment, as in the above-described embodiment, performs ON/OFF control of the switch section 3 based on an input command value X(n), to a closed circuit in which the switch section 3 is connected between the heater 4 and the AC power supply 5. In the power control apparatus 2, the output of the current transformer 6 is fetched to the current detection section 2H, and the signal processing section 2I detects the presence or absence of a wire break based on the detected output of the current detection section 2H, whereby treatment of a wire break of the heater can be correctly performed.

Claims

1. A control circuit (20) for performing ON/OFF control of a switch section (3) connected between an AC power supply (5) and a load;
 - wherein said control circuit (20) determines whether or not an AC power supply (5) waveform (i.e., AC waveform) polarity at a previous turning ON at said switch section (3) is the same as an AC

waveform polarity at a present turning ON;

wherein said control circuit (20) performs control to allow the present turning ON of said switch section (3) when it is determined that said polarities are not the same; and

wherein said control circuit (20) performs control to inhibit the present turning ON of said switch section (3) when it is determined that said polarities are the same.

2. The control circuit (20) according to claim 1, comprising:

- a polarity detection section (2F) for detecting said AC waveform polarity;

- a storage section (2G) for storing an AC waveform polarity at the time said switch section (3) is turned ON, from a detection output of said polarity detection section (2F);

- a signal processing section (2I) for determining whether or not the AC waveform polarity at the previous turning ON at said switch section (3) is the same as the AC waveform polarity at the present turning ON of said switch section (3), said polarities being stored by said storage section (2G), for allowing the present turning ON of said switch section (3) when it is determined that the AC waveform polarity at the present turning ON of said switch section (3) is not the same as the AC waveform polarity at the previous turned ON, and for inhibiting the present turning ON of said switch section (3) when it is determined that the AC waveform polarity at the present turning ON of said switch section (3) is the same as the AC waveform polarity at the previous turning ON.

3. The control circuit (20) according to claim 2, comprising:

- a load current detection section for detecting a load current from a current transformer (6) output,

- wherein said signal processing section (2I) detects the presence or absence of a wire break of said load based on an output of said load current detection section, and negates the output of said load current detection section when the AC waveform polarity at the previous turning ON of said switch section (3) is uncertain.

4. A control circuit (20) for performing ON/OFF control of a switch section (3) connected between an AC power supply (5) and a load;
 - wherein said control circuit (20) determines whether or not parity of the number of AC polarity alternations from a previous given point in time to a

turning ON point at said switch section (3) is the same as parity of the number of polarity alternations at a present turning ON;

wherein said control circuit (20) performs control to allow the present turning ON of said switch section (3) when it is determined that said parities are not the same; and

wherein said control circuit (20) performs control to inhibit the present turning ON of said switch section (3) when it is determined that said parities are the same.

5. The control circuit (20) according to claim 4, comprising:

a zero cross detection section (2K) for detecting zero cross of a voltage of said AC power supply (5);

a count detection section (2L) for counting the number of AC polarity alternations from the given point in time to turning ON point of said switch section (3) by using zero cross detection obtained at said zero cross detection section (2K), and for storing the parity of the number of polarity alternations; and

a signal processing section (2I) for obtaining the parity of the number of polarity alternations at the previous turning ON of said switch section (3) from said count detection section (2L), for determining whether or not the parity of the number of polarity alternations at the previous turning ON is the same as the parity of the number of polarity alternations at the present turning ON, for allowing the present turning ON of said switch section (3) when it is determined that said parities are not the same, and for inhibiting the present turning ON of said switch section (3) when it is determined that said parities are the same.

6. The control circuit (20) according to claim 5, comprising:

a load current detection section for detecting a load current from a current transformer (6) output,

wherein said signal processing section (2I) detects the presence or absence of a wire break of said load based on an output of said load current detection section, and negates the output of said load current detection section when the parity of the number of polarity alternations at the previous turning ON of said switch section (3), the parity being counted from said given point in time, is uncertain.

7. A power control apparatus (2) for outputting an output power command value at predetermined cycles

more than a half cycle of an AC power supply (5) in response to an input power command value, and for performing ON/OFF control of a switch section (3) connected between the AC power supply (5) and a load, in accordance with said output power command value to control power supply to be supplied to said load, said power control apparatus (2) comprising:

an output difference accumulating section (2C) for accumulating the difference between an output power command value and an input power command value;

an addition section (2D) for adding an input power command value and an output difference accumulated value accumulated at said output difference accumulating section (2C);

a comparison section (2E) for comparing a threshold with an added value which said addition section (2D) added, for outputting an output power command value as 100% when said added value is more than said threshold as a result of said comparison, and for outputting an output power command value as 0% when said added value is less than said threshold as a result of said comparison; and

a control circuit (20) according to any one of claims 1 to 6.

Fig. 1

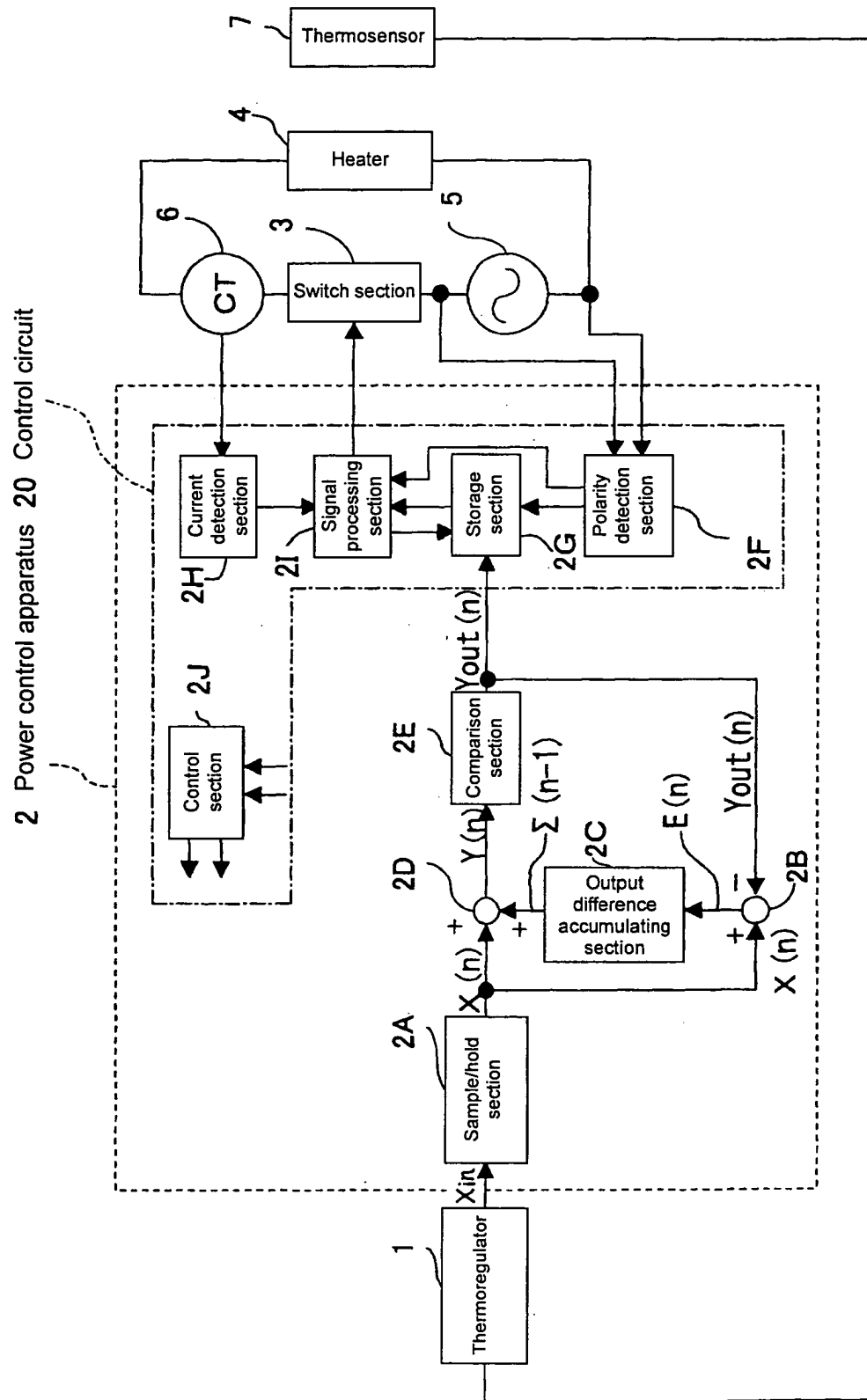


Fig. 2

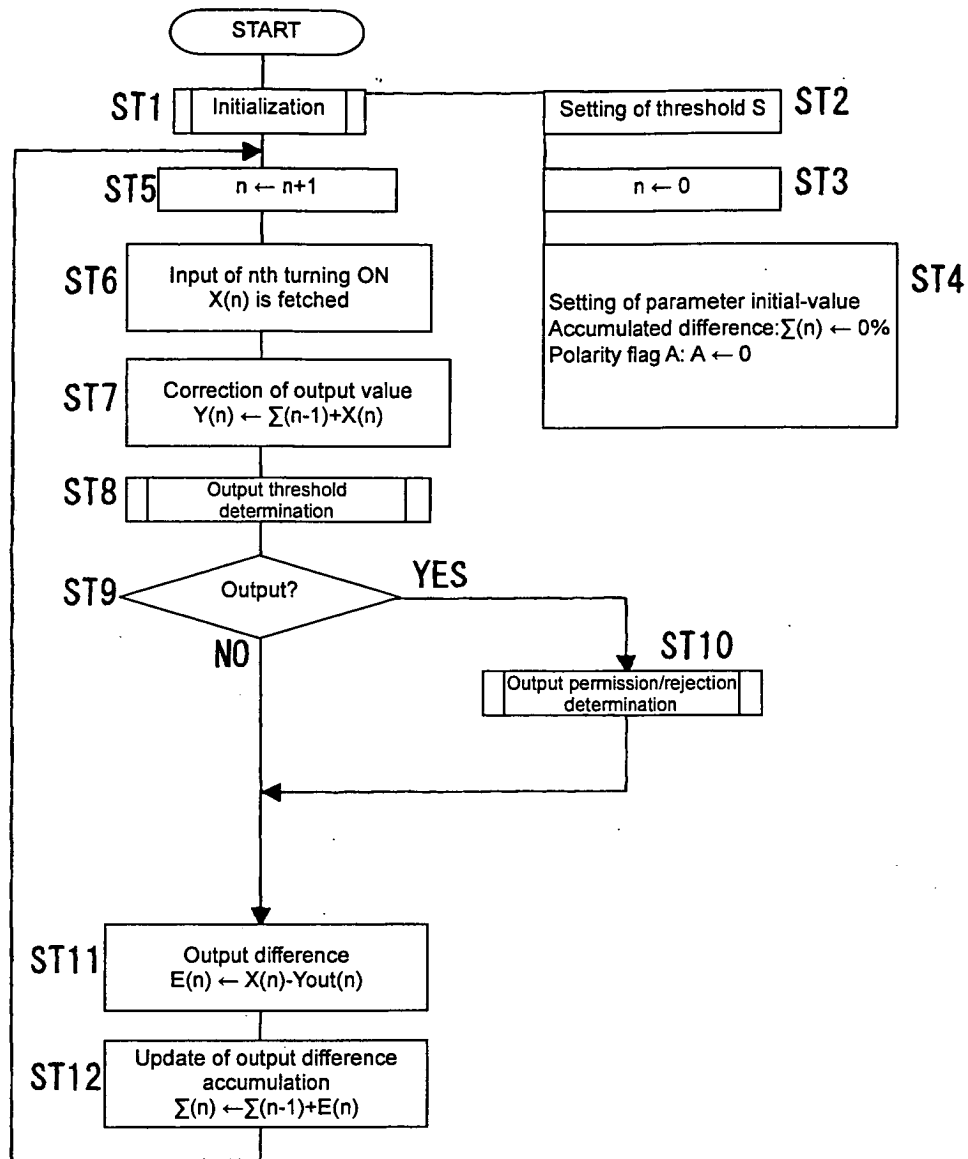
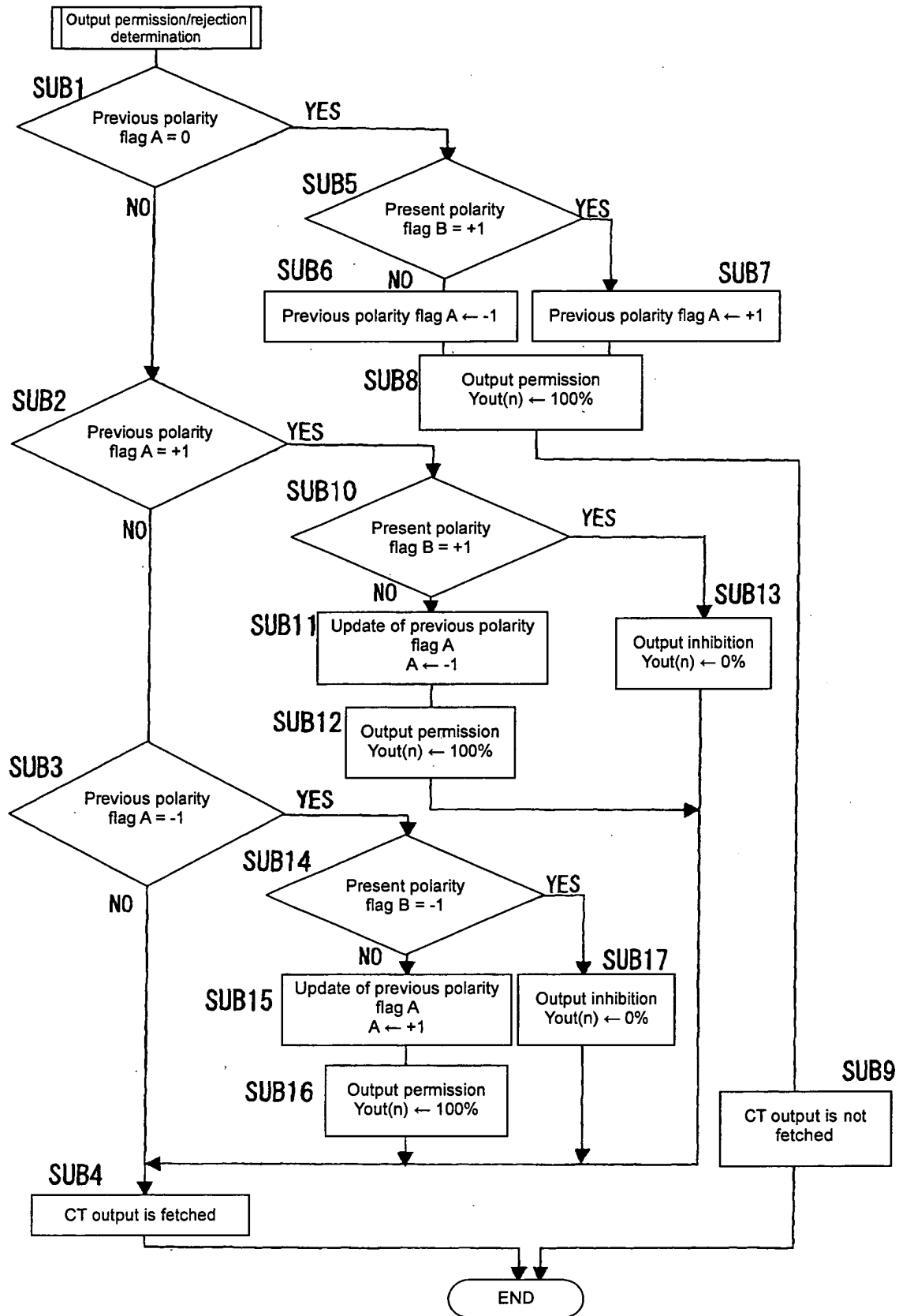


Fig. 3



Background art: control amount of 25%

Fig. 4A



Fig. 4B



Present invention art: control amount of 25%

Fig. 5A

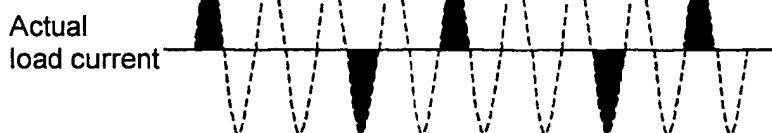


Fig. 5B



Background art: control amount of 50%

Fig. 6A



Fig. 6B



Present invention art: control amount of 50%

Fig. 7A

Actual
load current



Fig. 7B

CT output



Fig. 8

