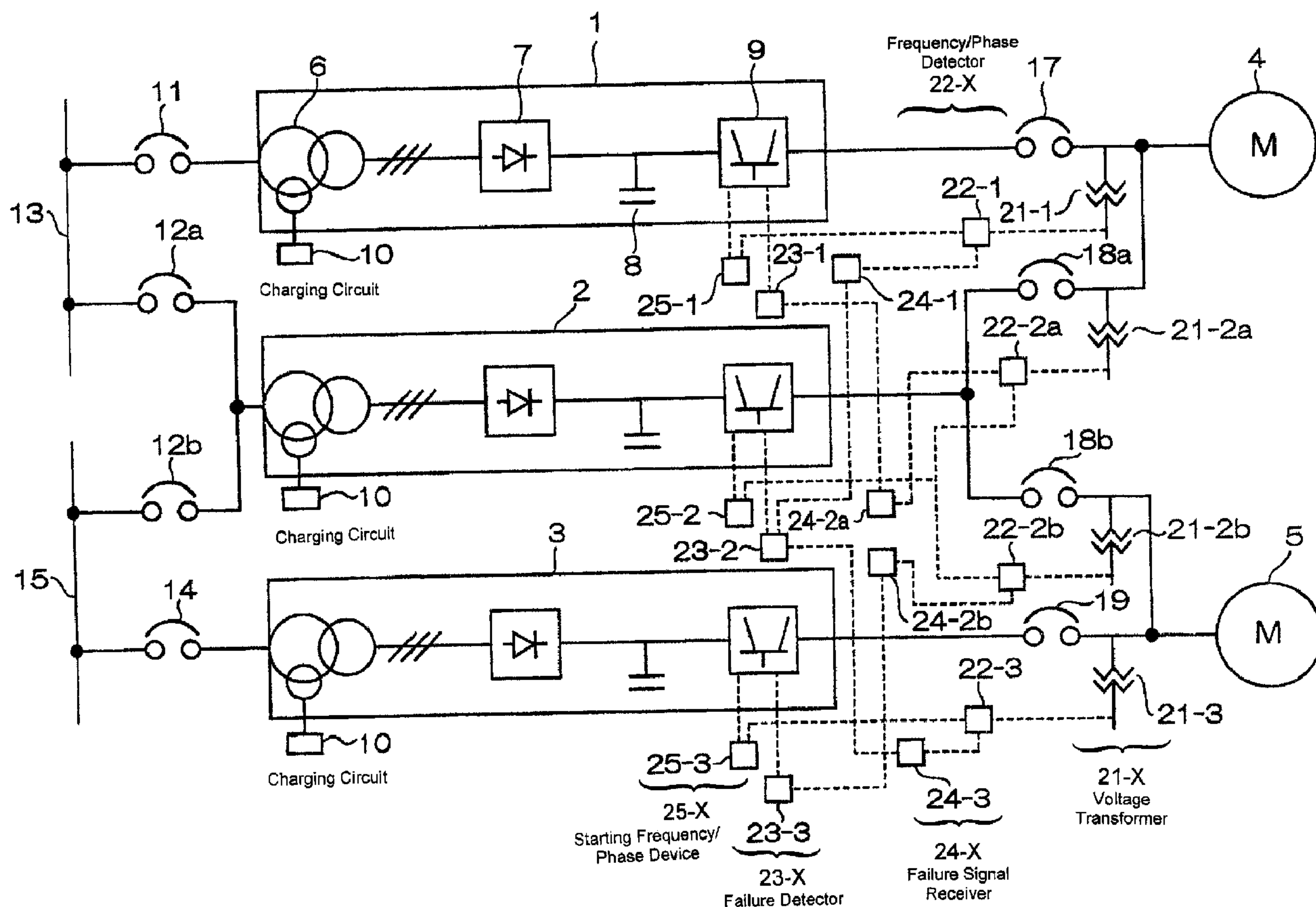




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 (54) Title: APPARATUS AND METHOD FOR DRIVING AN INDUCTION MOTOR



(57) Abrégé/Abstract:

An induction motor drive includes a plurality of inverters, a changeover switch which changes over outputs of the plurality of inverters to be supplied to one induction motor and a changeover controller which controls the changeover switch on the basis of a

(57) **Abrégé(suite)/Abstract(continued):**

failure detection signal of one inverter to change over from the one inverter to another inverter to start the other inverter so that the induction motor is driven. The changeover controller includes a frequency/phase detector which always detects a frequency and a phase of a terminal voltage of the induction motor and a starting frequency/phase setting device which controls a frequency and a phase at starting of the other inverter in accordance with detected values of the frequency/phase detector when the failure signal is inputted.

ABSTRACT OF THE DISCLOSURE

An induction motor drive includes a plurality of inverters, a changeover switch which changes over outputs of the plurality of inverters to be supplied to one induction motor and a changeover controller which controls the changeover switch on the basis of a failure detection signal of one inverter to change over from the one inverter to another inverter to start the other inverter so that the induction motor is driven. The changeover controller includes a frequency/phase detector which always detects a frequency and a phase of a terminal voltage of the induction motor and a starting frequency/phase setting device which controls a frequency and a phase at starting of the other inverter in accordance with detected values of the frequency/phase detector when the failure signal is inputted.

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APPARATUS AND METHOD FOR DRIVING AN INDUCTION MOTOR

FIELD OF THE INVENTION

The present invention relates to an induction motor drive which carries out adjustable speed operation of an induction motor by an inverter and more particularly to a technique effective when one inverter fails and the inverter is changed over from the failed inverter to another inverter to drive the induction motor.

BACKGROUND

The induction motor drive for carrying out adjustable speed operation of the induction motor by the inverter is widely used to carry out adjustable speed operation of various machines (hereinafter referred to as load) such as fan and pump. Further, in case of an important load which is not allowed to be stopped even if failure occurs, inverters are duplexed and when one inverter fails, the inverter is changed over from the failed inverter to the other inverter to continue the adjustable speed operation without stopping operation of the load.

20

For example, in a conventional induction motor drive a failure signal of a failed inverter is sent to the other inverter and after the other inverter confirms changeover of a switch connected between the induction motor and the other inverter, the inverter starts the

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operation of the induction motor. Especially, the other normal inverter sets a starting frequency so as to match the speed of the induction motor rotating inertially upon changeover, so that the changeover is made smoothly while the operation of the inverter is synchronized with the speed of the induction motor. Consequently, even if one inverter fails, it can be changed over to the other inverter, so that the adjustable speed operation of the induction motor can be continued without stopping operation of the induction motor.

Further, only inverter main circuits of an inverter are generally duplexed and an inverter controller is provided in common to both the inverter main circuits so that the same drive signals are always supplied to both the inverter main circuits and output voltages, phases and frequencies of both the inverter main circuits are synchronized with each other so that the inverter main circuits are changed over from one to the other. Consequently, variation in output (torque shock and the like) of a load upon changeover can be eliminated.

On the other hand, a changeover operation apparatus including an adjustable speed inverter which drives induction motors upon sudden adjustable speed operation at the time that induction motors are separated from a

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spinning line in which induction motors are group-operated and a normal operation inverter which is operated by changing over from the adjustable speed inverter to the normal operation inverter when the
5 induction motors are normally operated in the spinning line. Especially, the inverter to be used after changeover is previously started and a frequency and a phase of an output voltage of the inverter used before changeover are detected, so that the inverters are
10 changed over after the frequency and the phase of the output voltage of the inverter to be used after changeover are synchronized with those of the inverter used before changeover to thereby suppress variation in speed of the induction motor and shorten the changeover
15 time.

However, conventional systems, as previously discussed, have a problem that phases of the output voltage of the inverter and the terminal voltage
20 of the induction motor are not matched to each other and accordingly the output of the induction motor is varied depending on a phase difference therebetween, so that the changeover time until the induction motor is returned to the state before failure is lengthened.
25 Further, the apparatus has a problem that since switches on the power side and the load side are changed over after the failure signal of one inverter

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is received, to initially charge the inverter to be used after changeover and at the same time after the speed of the induction motor is detected to calculate a starting frequency on the basis of the detected value, 5 the inverter to be used after changeover is started, the changeover time is lengthened and the output and the speed of the induction motor are considerably reduced meanwhile.

In addition, certain conventional systems 10 also have a problem that since the inverter controller is provided in common to both the inverter main circuits so that the same drive signals are always supplied to both the inverter main circuits, it is impossible to deal with the case where the inverter 15 controller fails.

Moreover, certain conventional systems also presuppose that the inverter used before changeover is normal upon changeover and accordingly the invention cannot be applied to the case 20 where one inverter fails and the failed inverter is changed over to the other normal inverter.

SUMMARY

It is an object of the present invention to suppress variation in output of an induction motor 25 when one inverter is changed over to the other inverter due to failure of the one inverter to drive the induction motor.

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Certain exemplary embodiments can provide an induction motor driving apparatus including a plurality of inverters each including an inverter main circuit and an inverter controller to control the inverter main circuit, a changeover switch to change over outputs of the plurality of inverters to be supplied to one induction motor and a changeover controller to control the changeover switch on the basis of a failure detection signal of one inverter of said plurality of inverters to change over from the one inverter to another inverter of said plurality of inverters to start said another inverter so that the induction motor is driven, wherein the changeover controller includes a frequency/phase detector to detect a frequency and a phase of a terminal voltage of the induction motor and controls a frequency and a phase at starting of said another inverter in accordance with detected values of the frequency and the phase of the terminal voltage detected by the frequency/ phase detector when the failure detection signal is inputted; and each of the plurality of inverters includes an initial charging circuit to charge said another inverter when a circuit breaker, connected between an AC power supply and said another inverter, is opened to provide an initial charge to said another inverter before changing over from said one inverter to said another inverter; wherein said initial charging circuit provided separately from said another inverter for charging said another inverter during a waiting period thereof before changing over from said one inverter to said another inverter.

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Certain exemplary embodiments can provide an induction motor driving method comprising: changing over outputs of a plurality of inverters by a changeover switch to be supplied to one induction motor; controlling the changeover switch on the basis of a failure detection signal of one inverter of said plurality of inverters to change over from the one inverter to another inverter of said plurality of inverters by a changeover controller to start said another inverter so that the induction motor is driven; making the changeover controller control a frequency/phase detector to always detect a frequency and a phase of a terminal voltage of the induction motor; controlling a frequency and a phase at starting of said another inverter in accordance with detected values of the frequency and the phase of the terminal voltage detected by the frequency/ phase detector when the failure detection signal is inputted; charging said another inverter by an initial charging circuit, when a circuit breaker connected between an AC power supply and said another inverter is opened to provide an initial charge to said another inverter before changing over from said one inverter to said another inverter; and providing said initial charging circuit separately from said another inverter for charging said another inverter during a waiting period thereof before changing over from said one inverter to said another inverter.

Certain exemplary embodiments can provide an induction motor driving apparatus including a plurality of inverters each including an inverter main circuit and an inverter controller to control the inverter main circuit,

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a changeover switch to change over outputs of the plurality of inverters to be supplied to one induction motor and a changeover controller to control the changeover switch on the basis of a failure detection
5 signal of one inverter of said plurality of inverters to change over from the one inverter to another inverter of said plurality of inverters to start said another inverter so that the induction motor is driven, wherein the changeover controller includes a frequency/phase detector
10 to detect a frequency and a phase of a terminal voltage of the induction motor and controls a frequency and a phase at starting of said another inverter in accordance with detected values of the frequency and the phase of the terminal voltage detected by the frequency/ phase detector
15 when the failure detection signal is inputted; means for shortening a change over time from said one inverter to said another inverter, said means comprising each of the plurality of inverters including an initial charging circuit to charge said another inverter when a circuit
20 breaker, connected between an AC power supply and said another inverter, is opened to provide an initial charge to said another inverter before changing over from said one inverter to said another inverter; and wherein said initial charging circuit provided separately from said
25 another inverter for charging said another inverter during a waiting period thereof before changing over from said one inverter to said another inverter.

In order to solve the above problems, according to certain embodiments, an induction motor

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drive includes a plurality of inverters each having an inverter main circuit and an inverter controller to control the inverter main circuit, a changeover switch to change over outputs of the plurality of inverters to
5 be supplied to one induction motor and a changeover controller to control the changeover switch on the basis of a failure detection signal of one inverter to change over from the one inverter to another inverter to start the other inverter so that the induction motor
10 is driven. The changeover controller includes a frequency/phase detector to always detect a frequency and a phase of a terminal voltage of the induction motor and controls a frequency and a phase at starting of the other inverter in accordance with detected
15 values of the frequency and the phase of the terminal voltage detected by the frequency/phase detector when the failure detection signal is inputted.

More particularly, the frequency of the terminal voltage of the induction motor represents the
20 speed of rotation at the time that supply of driving power to an induction motor is stopped due to failure of one inverter and the induction motor rotates inertially. Accordingly, by always detecting the terminal voltage of the induction motor, the frequency
25 and the phase of the terminal voltage of the induction motor can be detected even during the period from the time that one inverter fails until the one inverter is changed over to another inverter. A frequency and a

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phase at starting of changeover of the inverter to be used after changeover can be set to be equal to the detected values to thereby synchronize the frequency and the phase of the output voltage of the inverter with the terminal voltage of the induction motor and accordingly variation in output such as variation in speed of the induction motor upon changeover can be suppressed. Further, since the frequency and the phase of the terminal voltage of the induction motor are always detected, the frequency and the phase at starting of changeover can be set simultaneously with inputting of the failure detection signal to thereby shorten the changeover time. Consequently, the inverter can be changed over to be started before the speed of the induction motor is reduced excessively, so that output variation such as torque variation of the induction motor can be minimized.

In addition to the above, it is desirable that the inverter includes an initial charging circuit having a switch which connects the inverter to the AC power supply when the circuit breaker for connecting the inverter to the AC power supply is opened, that is, when the inverter is on standby. In other words, generally, the inverter is started after the time required to charge a smoothing condenser of a DC circuit of the inverter. However, the provision of the initial charging circuit of the present invention does not require the time necessary to charge conductors of

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an electric circuit of the inverter to be used after
changeover and accordingly the start timing of the
inverter to be used after changeover can be advanced by
that time. Consequently, output variation such as
5 torque variation of the induction motor can be more
minimized.

According to certain embodiments, when one
inverter fails, the one inverter is changed over to
another inverter to drive the induction motor, so that
10 output variation of the induction motor upon changeover
can be suppressed.

Other objects, features and advantages of the
invention will become apparent from the following
description of the embodiments of the invention taken
15 in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram schematically
illustrating an induction motor drive according to an
embodiment of the present invention;

20 Fig. 2 is a timing chart showing changeover
control operation of the induction motor drive
according to the embodiment of the present invention;
and

Fig. 3 is a diagram showing change of an
25 output of the induction motor upon changeover to
explain the effects of the present invention.

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DESCRIPTION OF THE EMBODIMENTS

Embodiments of the present invention are now described with reference to the accompanying drawings. Fig. 1 is a block diagram illustrating an induction motor drive according to an embodiment of the present invention. As illustrated in Fig. 1, the induction motor drive of the embodiment includes three inverters 1, 2 and 3. Normally, the inverters 1 and 3 operate to drive induction motors 4 and 5, respectively, and when one of the inverters 1 and 3 fails, it can be changed over to the auxiliary inverter 2 which is provided in common to both the inverters 1 and 3. Further, when the inverter 2 fails in case where one of the induction motors 4, 5 is driven by the inverter 2, if the inverter 1 or 3 is recovered, the inverter 2 can be changed over to the inverter 1 or 3 corresponding to the induction motor 4 or 5 driven by the inverter 2.

Since the inverters 1, 2 and 3 have the same configuration, the configuration of the inverter 1 is described in detail and description of other inverters is omitted. The inverter 1 includes a transformer 6 for transforming inputted AC voltage, a rectifier 7 for converting AC voltage adjusted by the transformer 6 into DC voltage, a smoothing condenser 8 for smoothing the rectified DC voltage and an inverter main circuit 9 for inverting the smoothed DC voltage into AC voltage having set voltage, frequency and phase. Further, although not shown, the inverter main circuit 9 of the

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inverters 1, 2 and 3 includes an inverter controller for controlling the inverter main circuit 9 on the basis of an inputted command. In addition, the transformer 6 includes a winding connected to an
5 initial charging circuit 10.

Input terminals of the inverters 1 and 2 are connected to a common AC power bus 13 through circuit breakers 11 and 12a, respectively, and input terminals of the inverters 2 and 3 are connected to another
10 common AC power bus 15 through circuit breakers 12b and 14, respectively. Further, output terminals of the inverters 1 and 2 are connected in common to the induction motor 4 through circuit breakers 17 and 18a, respectively, and output terminals of the inverters 2
15 and 3 are connected in common to the induction motor 5 through circuit breakers 18b and 19, respectively.

The configuration of a changeover controller in the embodiment of the present invention is now described. Voltage transformers 21 (21-1, 21-2a, 21-2b
20 and 21-3) are connected to electric circuits on the load side of the circuit breakers 17, 18a, 18b and 19 of the inverters 1, 2 and 3. Outputs of the voltage transformers 21 are supplied to frequency/phase detectors 22 (22-1, 22-2a, 22-2b and 22-3). The
25 frequency/phase detector 22 is constituted by well-known phase locked loop (PLL) circuit and always detects a frequency and a phase of voltage corresponding to terminal voltage of the induction

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motor 4 or 5 detected by the voltage transformer 21.
The phase is detected by integrating the frequency.

Further, failure detectors 23 (23-1, 23-2 and 23-3) are provided in a corresponding manner to the 5 inverters 1, 2 and 3. When the failure detector 23 detects failure of the inverter 1, 2 or 3, the failure detector 23 supplies a failure signal to a failure signal receiver 24 of the inverter set as a changeover device. In other words, the failure detector 23-1 10 supplies the failure signal to the failure signal receiver 24-2a, the failure detector 23-2 supplies the failure signal to the failure signal receivers 24-1 and 24-3 and the failure detector 23-3 supplies the failure signal to the failure receiver 24-2b. Further, when 15 the failure detector 23 detects failure in the inverter corresponding thereto, the failure detector 23 controls to open the circuit breakers on the AC power side and the load side of the inverter. Moreover, when the failure signal receiver 24 receives the failure signal, 20 the failure signal receiver 24 controls to turn on or close the circuit breakers on the AC power side and the load side of the inverter corresponding thereto.

When the failure signal receiver 24 receives the failure signal, the failure signal receiver 24 25 supplies a trigger signal to the frequency/phase detector 22 of the inverter set as the changeover device. That is, the failure signal receiver 24-1 supplies the trigger signal to the frequency/phase

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detector 22-1, the failure signal receiver 24-2a to the
frequency/phase detector 22-2a, the failure signal
receiver 24-2b to the frequency/phase detector 22-2b,
and the failure signal receiver 24-3 to the
5 frequency/phase detector 22-3.

The frequency/phase detector 22 supplies
detected values of a frequency and a phase at the time
that the trigger signal is supplied thereto, to a
starting frequency/phase setting device 25 of the
10 inverter corresponding thereto. That is, the
frequency/phase detectors 22-1 supplies the detected
values of the frequency and the phase to the starting
frequency/phase setting device 25-1, the
frequency/phase detector 22-2a and 2b to the starting
15 frequency/phase setting device 25-2, and the
frequency/phase detector 22-3 to the starting
frequency/phase setting device 25-3.

The starting frequency/phase setting device
25 (25-1, 25-2 and 25-3) supplies a command value of a
20 frequency and a phase at starting to the inverter
controller of the inverter 1 - 3 corresponding thereto.
The inverter controller controls the inverter main
circuit to supply an output voltage having the starting
frequency and phase corresponding to the command value
25 to the induction motor 4 or 5 through the circuit
breaker 17 or 18a or the circuit breaker 18b or 19.

Operation of the embodiment configured as
above is now described with reference to the timing

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chart showing the operation of the embodiment shown in Fig. 2. For simplification of description, the case where failure occurs in the rectifier 7, the inverter main circuit 9 or the inverter controller constituting the inverter 1 is described by way of example. The frequency/phase detector 22-2a always takes in the detected voltage corresponding to the terminal voltage of the induction motor 4 from the voltage transformer 21-2a and always detects the frequency and the phase of the detected voltage.

When failure in the inverter 1 is detected by the failure detector 23-1 at time t_0 , the circuit breakers 11 and 17 are turned off at the same time. In addition, a switch of the initial charging circuit 10 which initially charges the inverter 2 during a waiting period is opened. Thereafter, the circuit breakers 12a and 18a of the inverter 2 to which the failed inverter 1 is changed over are turned on simultaneously at time t_1 . Further, the frequency/phase detector 22-2a is triggered by the failure signal supplied from the failure detector 23-1 and supplies the detected values of the frequency and the phase at that time to the starting frequency/phase setting device 25-2. The starting frequency/phase setting device 25-2 supplies the command value of the frequency and the phase at starting to the inverter controller of the inverter 2 in accordance with the detected value of the frequency and the phase supplied thereto. Consequently, the

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inverter 2 can be started immediately since the inverter 2 has been already charged initially.

Then, at time t_2 , the inverter controller starts the inverter main circuit 9 in accordance with the command value of the frequency and the phase at starting supplied from the starting frequency/phase setting device 25-1. Consequently, the output voltage having the frequency and the phase corresponding to the terminal voltage of the induction motor 4 is supplied to the induction motor 4 through the circuit breaker 18a, so that the induction motor 4 rotating inertially is accelerated smoothly and is rapidly recovered to generate the output before failure.

Change of the output of the induction motor 4 at this time is shown by curve 30 of Fig. 3. As shown in Fig. 3, when the circuit breaker 17 is opened or turned off at time t_0 due to the failure of the inverter 1, the induction motor 4 begins to reduce its output by only inertial rotating force. Thereafter, at time t_2 , when the inverter 2 is started at the frequency and the phase corresponding to the terminal voltage of the induction motor 4 at this time, the induction motor 4 is accelerated smoothly and is rapidly recovered to generate the output before failure at time t_3 .

As described above, according to the embodiment, since the frequency/phase detector 22-2a always detects the frequency and the phase of the

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detected voltage corresponding to the terminal voltage of the induction motor 4, the starting frequency and phase of the inverter 2 to be used after changeover can be immediately set upon changeover caused by failure.

5 In other words, the time for setting the starting frequency and phase anew after the inverter is changed over is not required and accordingly the changeover time can be shortened by that time.

Generally, the inverter requires initial
10 charging at its starting, although in the embodiment since the initial charging circuit 10 is provided to initially charge the inverter during a waiting period before changeover, the changeover time of the inverter can be shortened by the initial charging time as
15 compared with the case where the initial charging is made after changeover.

Heretofore, generally, the circuit breakers on the AC power side and the load side of the inverter are opened and closed in a predetermined order so that
20 when the circuit breaker (e.g. 11) on the AC power side and the circuit breaker (e.g. 17) on the load side of the inverter are turned off or opened, the circuit breaker on the load side is opened after the circuit breaker on the power side is opened and when the
25 circuit breakers are turned on or closed, the circuit breakers are turned on in the reverse order. In this respect, according to the embodiment, the circuit breakers on the AC power side and the load side are

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opened and closed simultaneously as shown in Fig. 2 and accordingly the delay of the changeover time can be shortened even from this standpoint.

As described above, according to the
5 embodiment, when one inverter fails, operation can be changed over from the one inverter to the other normal inverter in a shortest time, so that reduction of the output of the induction motor upon changeover of the inverter can be minimized. Accordingly, influence on
10 operation of the whole system such as a plant due to the reduced output of the induction motor can be avoided, so that the reliability of the plant can be improved.

Consequently, energy-saving operation using
15 the inverter can be applied to the plant in which application of the inverter thereto has a problem when influence upon failure of the inverter is considered. Further, since it is not necessary to directly mount a speed detector to a shaft of the induction motor,
20 application of the present invention is easy.

In the embodiment, two inverters and one standby inverter for two induction motors constitute a redundant system or a duplexed system, although the present invention is not limited thereto and N
25 inverters and one standby inverter for N induction motors may constitute an N-to-1 redundant system. Consequently, the cost for constructing a system into a redundant form can be reduced.

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It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and
5 various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.

CLAIMS:

1. An induction motor driving apparatus including a plurality of inverters each including an inverter main circuit and an inverter controller to control the inverter main circuit, a changeover switch to change over outputs of the plurality of inverters to be supplied to one induction motor and a changeover controller to control the changeover switch on the basis of a failure detection signal of one inverter of said plurality of inverters to change over from the one inverter to another inverter of said plurality of inverters to start said another inverter so that the induction motor is driven, wherein

the changeover controller includes a frequency/phase detector to detect a frequency and a phase of a terminal voltage of the induction motor and controls a frequency and a phase at starting of said another inverter in accordance with detected values of the frequency and the phase of the terminal voltage detected by the frequency/phase detector when the failure detection signal is inputted; and

each of the plurality of inverters includes an initial charging circuit to charge said another inverter when a circuit breaker, connected between an AC power supply and said another inverter, is opened to provide an initial charge to said another inverter before changing over from said one inverter to said another inverter;

wherein said initial charging circuit provided separately from said another inverter for charging said another inverter during a waiting period thereof before changing over from said one inverter to said another inverter.

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2. An induction motor driving apparatus according to claim 1, wherein the frequency/phase detector includes a phase locked loop (PLL) circuit which is supplied with a detected value of the terminal voltage.

5

3. An induction motor driving method comprising:
changing over outputs of a plurality of inverters by a changeover switch to be supplied to one induction motor;
controlling the changeover switch on the basis of a
10 failure detection signal of one inverter of said plurality of inverters to change over from the one inverter to another inverter of said plurality of inverters by a changeover controller to start said another inverter so that the induction motor is driven;

15 making the changeover controller control a frequency/phase detector to always detect a frequency and a phase of a terminal voltage of the induction motor;
controlling a frequency and a phase at starting of said another inverter in accordance with detected values of
20 the frequency and the phase of the terminal voltage detected by the frequency/phase detector when the failure detection signal is inputted;

charging said another inverter by an initial charging circuit, when a circuit breaker connected between an AC
25 power supply and said another inverter is opened to provide an initial charge to said another inverter before changing over from said one inverter to said another inverter; and

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providing said initial charging circuit separately from
said another inverter for charging said another inverter
during a waiting period thereof before changing over from
5 said one inverter to said another inverter.

4. An induction motor driving apparatus including a
plurality of inverters each including an inverter main
circuit and an inverter controller to control the inverter
10 main circuit, a changeover switch to change over outputs of
the plurality of inverters to be supplied to one induction
motor and a changeover controller to control the changeover
switch on the basis of a failure detection signal of one
inverter of said plurality of inverters to change over from
15 the one inverter to another inverter of said plurality of
inverters to start said another inverter so that the
induction motor is driven, wherein

the changeover controller includes a frequency/phase
detector to detect a frequency and a phase of a terminal
20 voltage of the induction motor and controls a frequency and
a phase at starting of said another inverter in accordance
with detected values of the frequency and the phase of the
terminal voltage detected by the frequency/phase detector
when the failure detection signal is inputted;

25 means for shortening a change over time from said one
inverter to said another inverter, said means comprising
each of the plurality of inverters including an initial
charging circuit to charge said another inverter when a
circuit breaker, connected between an AC power supply and
30 said another inverter, is opened to provide an initial
charge to said another inverter before changing over from
said one inverter to said another inverter; and

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wherein said initial charging circuit provided
separately from said another inverter for charging said
another inverter during a waiting period thereof before
changing over from said one inverter to said another
5 inverter.

FIG.1

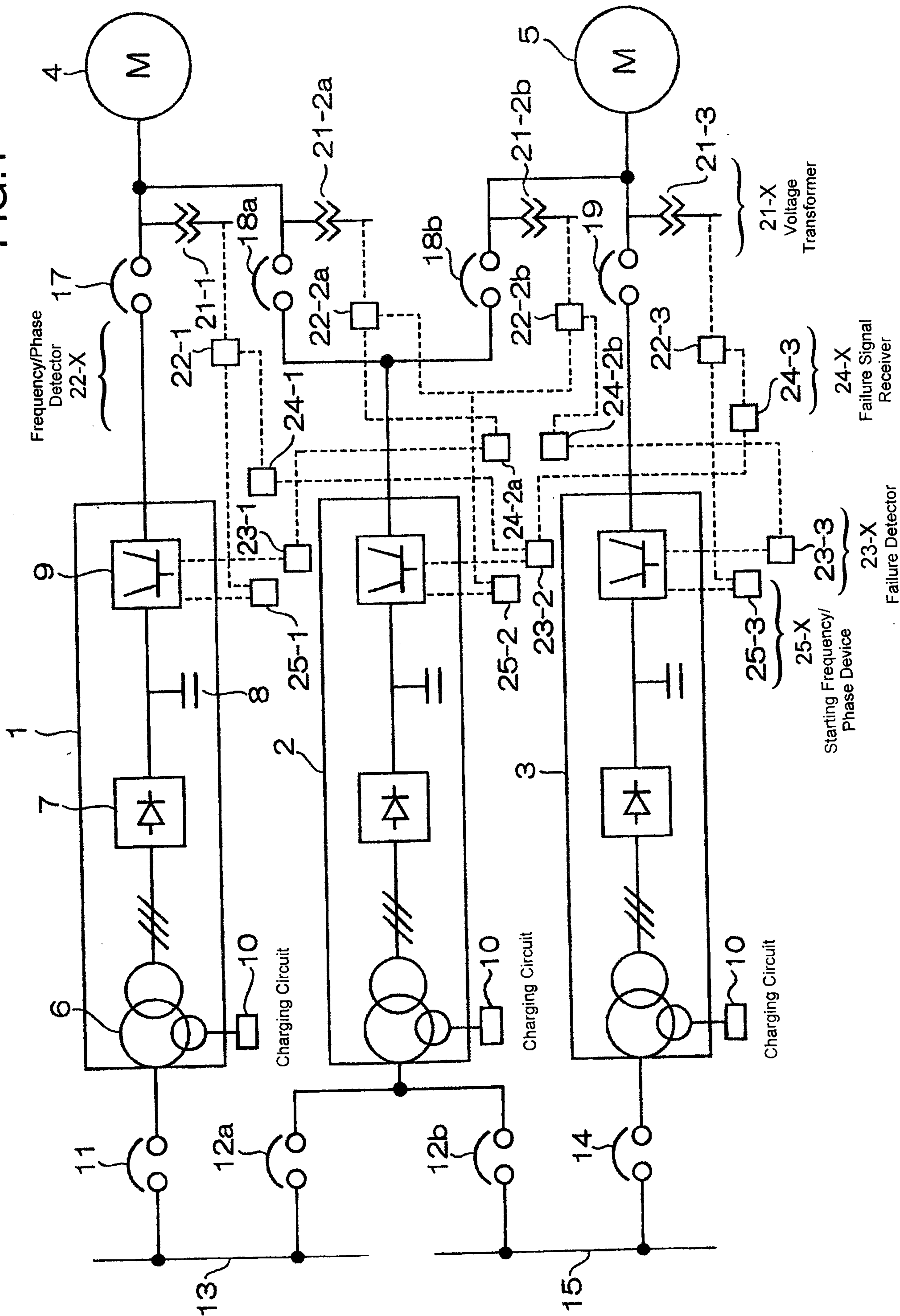


FIG.2

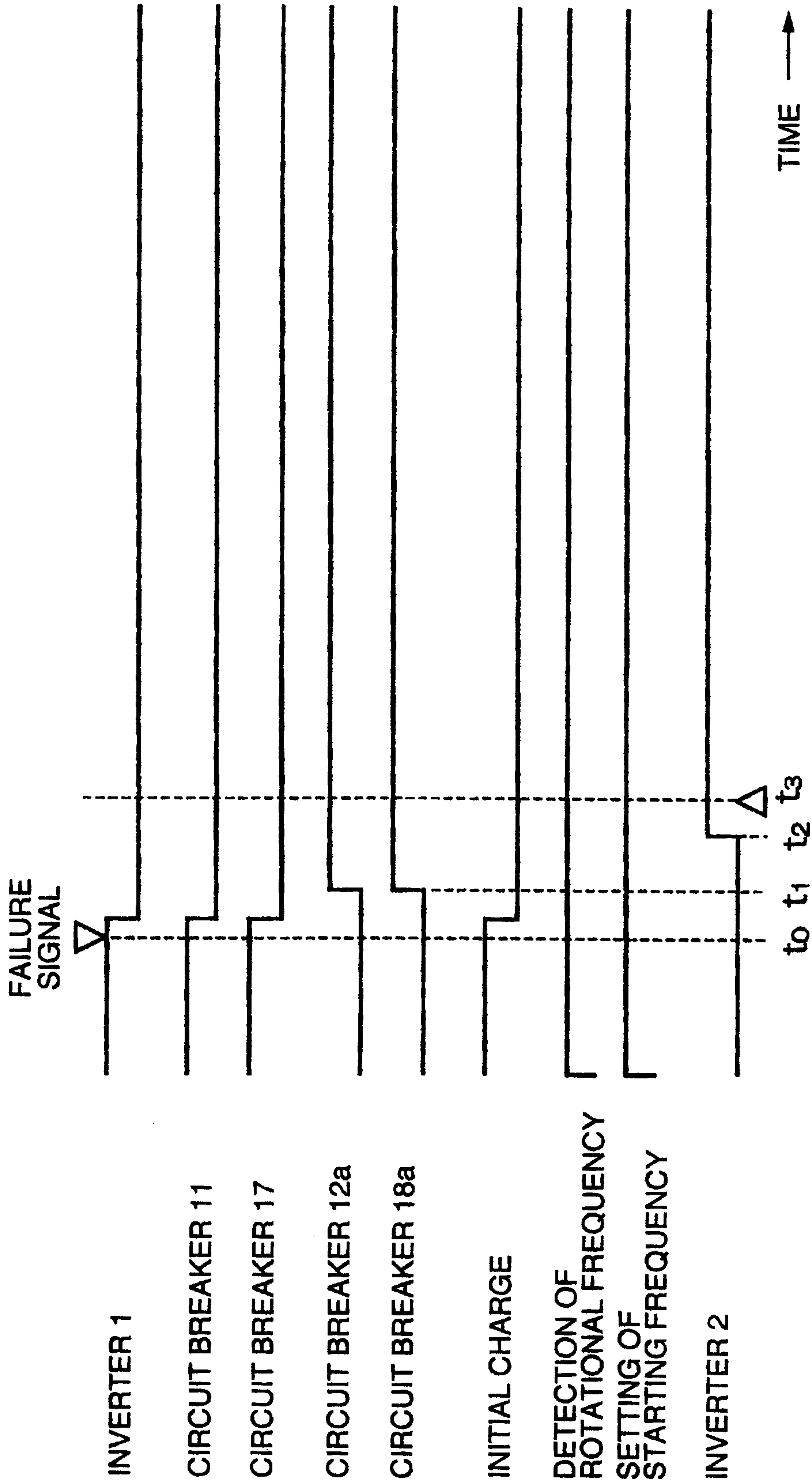


FIG.3

