

EARTH LEAKAGE-CURRENT PROTECTION DEVICE

BACKGROUND OF THE INVENTION

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This invention relates to an earth leakage breaker having objects of protecting the human body from electrical shock caused by earth leakage current in ranges higher than commercial frequencies and also having a current sensing characteristic that prevents accidental operation from occurring due to earth leakage current resulting from stray capacitance in the high frequency range. This invention is applicable not only to earth leakage breakers with make-or-break contacts to cut out power but also to such equipments without make-or-break contacts as earth leakage relays configured to detect earth leakage current and generate a tripping signal which is supplied to other switchgear.

Description of Related Art

Earth leakage breakers having the object of protecting the human body from electrical shock and preventing malfunction or unnecessary operation in the high frequency range are known in such conventional art as described in EP Publication EP0 464 516 A2.

This prior art is an earth leakage-current protection system comprised of a high sensitivity, high speed type earth leakage breaker (hereinafter high sensitivity ELB) and a middle sensitivity, delayed action type earth leakage breaker(hereinafter middle sensitivity ELB). The high sensitivity ELB of this earth leakage-current protection system has a current sensing frequency characteristic set lower than a threshold value (for instance, a threshold value defined by the International Electrotechnical Commission (IEC) 479-2) for protecting a human body from earth leakage current in ranges exceeding commercial frequencies. The middle sensitivity ELB has a current sensing frequency characteristic with an abrupt rise near ranges exceeding commercial power frequencies.

In this conventional leakage protection system, the middle sensitivity ELB is connected in cascade in the upper stage of the high sensitivity ELB. When an earth leakage current having a frequency higher than commercial power frequencies flows through the circuit, and its magnitude exceeds the threshold value of the high sensitivity ELB, the high sensitivity ELB detects the earth leakage current and cuts off the circuit. As the current sensing frequency characteristic of the middle sensitivity ELB in the upper stage is determined so as to be raised abruptly at a frequency exceeding commercial power frequencies, the middle sensitivity ELB does not work at frequency ranges higher than the commercial frequencies. Therefore, an earth leakage current exceeding the threshold value and potentially harmful to the human body is cut out by the high sensitivity ELB in the lower stage, which prevents malfunction of the middle sensitivity ELB in the upper stage. On the other hand, the middle sensitivity ELB cuts out the



circuit when electrical short circuit occurs to prevent further upper stages of the circuit from undesirable cut-out.

The drawbacks of the earth leakage-current protection system of the prior art are described below referring to Figs. 7, 8 and 9.

Figure 7 is a drawing showing the leakage current occurring due to stray capacitance between the circuit and the ground. Figure 8 shows the earth leakage-current protection system of the related art utilizing a high sensitivity ELB. Figure 9 is a graph showing the frequency factor of the current causing ventricular fibrillation versus frequency of the current described in IEC479-2. This graph indicates coefficients of the threshold value of the current causing ventricular fibrillation for respective frequency. For instance, the threshold value, compared to that at commercial frequency, becomes approximately fivefold at 300 Hz and increases continuously up to nearly fourteenfold at 1 kHz.

An example of a circuit including an inverter as a load (hereinafter inverter load) for the earth leakage breaker is shown in Fig. 7. Since a high frequency current flows in the inverter load, the earth leakage current derives most from current flowing through stray capacitance. Stray capacitance is greatly influenced by the condition of the wirings installed. When stray capacitance in the circuit is large, a large leakage current consequently flows through the capacity.

An example of protection coordination in a circuit having an inverter load is shown in Fig. 8. In this example, the high sensitivity, high speed type earth leakage breaker ELB3 (hereinafter high sensitivity breaker ELB3) is installed directly on the power supply side of the inverter INV that drives the motor IM2. The middle sensitivity, delayed action type earth leakage breaker ELB2 (hereinafter middle sensitivity breaker ELB2) is installed on the power supply side (i.e. upper stage) of the high sensitivity breaker ELB3. Another middle sensitivity, delayed action type earth leakage breaker ELB1 (hereinafter middle sensitivity breaker ELB1) is installed on the power supply side (i.e. upper stage) of middle sensitivity breaker ELB2. Thus the high sensitivity breaker ELB3 is installed between the load at its lower stage and the middle sensitivity breaker ELB2 at its upper stage. By setting such characteristics of high sensitivity breaker ELB3 and middle sensitivity breaker ELB2 as high sensitivity, high speed type and middle sensitivity, delayed action type respectively, high sensitivity breaker ELB3 is triggered first when a leakage current is detected in the circuit including the inverter load and breaks (cuts out) only the circuit where the leakage has occurred. Thus high sensitivity breaker ELB3 functions so as to prevent the other circuits from being cut out undesirably and it performs protection coordination of the circuit with the middle sensitivity breaker ELB2 installed on its upper stage.

The current sensing frequency characteristic of the leakage protection system is described referring to Fig. 6.



In Fig. 6, A is a characteristic curve showing the current sensing frequency characteristic of the middle sensitivity breaker ELB2. The current sensing frequency characteristic of the middle sensitivity breaker ELB1 has the analogous curve to that of middle sensitivity breaker ELB2 and is located at a position somewhat to the upper left of that of middle sensitivity breaker ELB2. However the characteristic of middle sensitivity breaker ELB1 is not shown in the drawing in order to simplify the depiction. The current sensing frequency characteristic for the conventional high sensitivity breaker ELB3 is shown by the curve B.

The current sensing frequency characteristic curve A for the middle sensitivity breaker ELB2 maintains a slight slope up to approximately 90 Hz and then increases with an abrupt rise. The current sensing frequency characteristic curve B for the high sensitivity breaker ELB3 maintains a gradual slope up to 1 kHz and then increases between 1 kHz and 10 kHz with a similar slope to threshold values of the ventricular fibrillation in IEC479-2. Since the high sensitivity breaker ELB3 is provided in order to protect the human body from such electrical harm as electrical shock, it has higher sensitivity for earth leakage current than that of the middle sensitivity breaker ELB2.

Generally, it is extremely difficult to specify the stray capacitance between a circuit and the ground. This brings about extreme difficulty in selecting equipment on the basis of the stray capacitance when installing an earth leakage protection device. Further, most current will act as noise current when it has frequencies involved in the high frequency region i.e., frequency regions higher than commercial power frequencies. These noise current have a tendency of flowing into the circuit path easily through the stray capacitance. Therefore, when making use of the current sensing frequency characteristic of the high-speed high-sensing leakage breaker in the high frequency region as described in EPO464516A2, the large drawback exists that undesirable operation occurs when noise current is detected due to the high sensitivity.

SUMMARY OF THE INVENTION

It is therefore an object of the invention in view of the above, to provide an earth leakage protection device that fulfills the purposes of protecting the human body from electrical shock caused by leakage current of high frequency and of preventing undesirable tripping from occurring in similar devices with an inverter load.

In order to achieve these objects the earth leakage protection device of this invention is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value, wherein





the tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range. This current sensing frequency characteristic is set to be below a specified threshold value within the first frequency range, the current sensing frequency characteristic is set to make a sharp increase in the second frequency range which exceeds the first frequency range and the current sensing frequency characteristic is set to be substantially infinite at all frequencies within this frequency range, which exceeds the second frequency range.

Further, the ground leakage protection device of this invention is provided with a leakage current sensing means and a tripping signal issuing means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value of which;

the tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range. This current sensing frequency characteristic is set to be below a specified threshold value within the first frequency range to protect the human body from harm. The current sensing frequency characteristic is set to make a sharp increase in the second frequency range which exceeds the first frequency range and the current sensing frequency characteristic is set to be essentially infinite at all frequencies within this frequency range, which exceeds the second frequency range.

Yet further, the earth leakage protection device of this invention is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value of which;

the tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range. This current sensing frequency characteristic is set to be below a specified threshold value from commercial frequencies to 1 kHz to protect the human body from electrical harm. The current sensing frequency characteristic is set to make a sharp increase in the second frequency range which exceeds 1 kHz and extends to 2 kHz. The current sensing frequency characteristic is set to be substantially infinite at all frequencies within this frequency range, which exceeds the second frequency range.

Even still further, the earth leakage protection device of this invention is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value of which;

the tripping signal generating means has a low-pass filter. The frequency characteristic of the low-pass filter is set to be below a specified threshold value within commercial frequencies to 1 kHz, in order to protect the human body from electrical harm. The current sensing frequency characteristic is set to make an abrupt increase in the second frequency range which exceeds 1 kHz and extends to 2 kHz.

Yet still further, the earth leakage protection device of this invention is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value of which;

the tripping signal generating means has a low-pass filter. The frequency characteristic of the low-pass filter is set to be below a specified threshold value within commercial frequencies to 1 kHz, in order to protect the human body from electrical harm by arranging for the impedance to increase along with an increase in frequency. In the second frequency range which exceeds 1 kHz and extends to 2 kHz, the impedance is set to make an abrupt rise along with an increase in the frequency. In the frequency range exceeding 2 kHz, the impedance is set to be substantially infinite for all frequencies within this frequency range.

An earth leakage protection device of this invention can therefore be provided which fulfills the purposes of protecting the human body from electrical shock caused by leakage current of high frequency and of preventing undesirable tripping from occurring in similar devices with an inverter load.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram showing the configuration of the earth leakage protection device in one embodiment of this invention.

Figure 2 is timing charts showing sample operation of the earth leakage protection device in one embodiment of this invention.

Figure 3 is timing charts showing another sample operation of the earth leakage protection device in one embodiment of this invention.

Figure 4 is a block diagram showing the structure of the low-pass filter in one embodiment of this invention.

Figure 5 is a graph showing the current sensing frequency characteristic in the earth leakage protection device in one embodiment of this invention.

Figure 6 is a graph comparing current sensing frequency characteristics in one embodiment of the earth leakage protection device of this invention with current sensing frequency characteristics in the related art.

Figure 7 is a descriptive drawing showing leakage current due to stray capacitance between the circuit and ground.

Figure 8 is a block diagram showing connections in the leakage protection system utilizing high-speed high sensing leakage breakers of the related art.

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Figure 9 is a graph showing factors relating to changes in size of current causing ventricular fibrillation versus frequency in IEC479-2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of this invention will now be described referring to Fig. 1 through Fig. 6.

The embodiment of this invention is applicable to electronic type earth leakage protection devices that amplify the output from the secondary of a zero-phase current transformer (hereinafter ZCT) to trigger a tripping device. The example in this embodiment is applied not only to an earth leakage breaker with make-or-break contacts but also to an equipment without make-or-break contacts such as leakage relay configured to detect an earth leakage current and generate a tripping signal to be supplied to other switchgear.

A block diagram showing the configuration of the earth leakage protection device of this embodiment is given in Fig. 1. Figure 2 is timing charts showing the sample operation of the earth leakage protection device in the embodiment of this invention. Figure 3 is another set of timing charts showing another example of operation in this embodiment. A block diagram showing the structure of the low-pass filter is given in Fig. 4. Figure 5 is a graph showing the current sensing frequency characteristic in the circuit operation in Figs. 2 and 3. The graph in Fig. 6 compares current sensing frequency characteristics in one embodiment of the earth leakage protection device of this invention with current sensing frequency characteristics in the device of the related art.

The earth leakage protection device of this embodiment is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected earth leakage current reaches a specified value.

The tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range. These frequency ranges are grouped into the first, second and third frequency ranges. Frequencies involved in the second range exceed those involved in the first range, and frequencies involved in the third range exceed those involved in the second range. The current sensing frequency characteristic is set to be below a specified threshold value within the first frequency range. The current sensing frequency characteristic is set to make an abrupt rise or increase in the second frequency range. The current sensing frequency characteristic is set to be substantially infinite at all frequencies within the third frequency range.

More specifically, the ZCT 7, as the leakage current sensing means, detects an imbalance in the currents flowing through the earth leakage breaker installed in the circuit path between the power source and the load. When earth leakage occurs, electrical currents get unbalanced and output current is induced



in the ZCT 7 by this unbalanced currents. This current output from the ZCT 7 is converted to an electrical voltage signal in a signal converter 1. This voltage signal is supplied to a leakage detector 3 by means of the primary low-pass filter (hereafter LPF) 2. The leakage detector 3 generates a tripping signal to an SCR drive means 4 when the leakage current reaches a specific value. Then this SCR drive means 4 supplies a signal to the gate of an SCR5. This signal turns on the SCR 5 and a tripping mechanism 6 is triggered. The tripping means opens the make-or-break contacts provided in the circuit path by the resultant mechanical action to cut out the circuit. Namely, the LPF 2 and the leakage detector 3 function as a tripping signal generating means. The power supply 8 supplies power to the signal converter 1, LPF 2, leakage detector 3, SCR drive means 4 and tripping device 6.

In this embodiment, the frequency ranges are; the first frequency range which is set to be from commercial frequencies (50/60 Hz) to 1 kHz, the second frequency range which is set to exceed 1 kHz and extend to 2 kHz, and the third frequency range which is set to exceed 2 kHz. These frequency ranges are set by the LPF2.

The frequency characteristic of the LPF 2 is set to be below a specified threshold value in the range from commercial frequencies to 1 kHz in order to protect the human body from harm, by setting the impedance to increase along with increases in frequency. In the second frequency range which exceeds 1 kHz and extends to 2 kHz, the impedance is set to make a sharp rise along with an increase in the frequency. In the second frequency range, in other words, all frequencies exceeding 2 kHz, the impedance is set to be substantially infinite.

This arrangement assigns a different current sensing frequency characteristic in the tripping signal generating means to the frequency ranges. The current sensing frequency characteristic of the earth leakage breaker is set to be below a specified threshold value within the first frequency range in order to protect the human body from electrical shock. The current sensing frequency characteristic is set to make an abrupt rise in the second frequency range. The current sensing frequency characteristic is set to be substantially infinite at all frequencies within the third frequency range.

The frequency ranges are grouped as described above for the following reasons. The carrier frequencies for inverters on the market have previously been established in a range from 1 kHz to 16 kHz so that a current sensing frequency characteristic are assigned below 1 kHz to respond at a leakage current below the threshold value for ventricular fibrillation as described in IEC479-2; a current sensing frequency characteristic with an abrupt rise in the frequency band exceeding 1 kHz and extending to 2 kHz; and a current sensing frequency characteristic substantially infinite at all frequencies included within the range exceeding 2 kHz. Therefore the current sensing characteristic in the earth leakage breaker of this embodiment is set to be infinite at frequencies greater than 2 kHz. Namely, this frequency range becomes

a dead zone, which prevents the undesirable operation from occurring by noise current straying into the circuit due to stray capacitance.

In this embodiment, the primary filter LPF 2 is a filter having a similar characteristic of gain to that of the frequency characteristic of threshold value for ventricular fibrillation described in IEC479-2.

An ordinary CR filter shown in Fig. 4 can be used as the primary filter LPF2. The frequency characteristic of the primary LPF2 is set to be below a specified threshold value within commercial frequencies to 1 kHz, in order to protect the human body from such electrical harm as electrical shock. Signals passing through the LPF 2 are input to the leakage detector 3. Common commercially available ICs may be utilized as the leakage detector 3. A buffer 10 and a secondary LPF 12 may be provided between the primary LPF2 and the leakage detector 3 to improve noise tolerance. The LPF1 is set in such cases to cut frequencies higher than approximately 3 kHz.

As shown in Fig. 2, the leakage detector 3 compares the upper and lower values of the input signal waveform of the half-wave length T1 with the threshold level. The No. 1 comparator timer (not shown in drawing) inside the leakage detector 3 contains the lower threshold level and outputs a positive pulse only when a leakage current is detected by an input signal waveform that reaches this lower threshold level. The rising time of the pulse from zero-level to the threshold level is defined as TW1 in this case.

In the same way, the No. 2 comparator timer (not shown in drawing) inside the leakage detector 3 contains the upper threshold level and outputs a positive pulse only when a leakage current is detected by an input signal waveform that reaches this upper threshold level. The rising time (hereinafter pulse rise time) of the pulse from zero-level to the threshold level is defined as TW2 in this case.

A positive pulse is output when an input pulse waveform is again input to the comparator timer.

The pulse rise times TW1 and TW2 can be set by changing the circuit constants, which is defined by filter capacitance and resistor values of the No.1 comparator timer and the No. 2 comparator timer installed in the leakage detector 3. The desired setting can be changed also in a digital type system by altering the counted value. In this embodiment, the timer is set by changing the filter capacitance contained in the timer circuit while a fixed threshold value has been set. When a commercially available IC is used as the leakage detector 3, the rise slope of the No.1 comparator timer and the No. 2 comparator timer is usually changed by altering the capacitance of the externally installed filter in order to set the time required to reach the timer threshold level.

Thus, this circuit is configured to generate an SCR drive signal regarding that a leakage current is detected, when three waveforms have been verified in the leakage detector 3, or only when the input signal



has reached a minimum specified magnitude (threshold level) or the input signal has continued specified time (TW1 or TW2).

In Fig. 3 on the other hand, when a high frequency signal with a half-wavelength T2 ($T2 < T1$) is input to the leakage detector 3, output of neither of the No.1 comparator timer nor the No. 2 comparator timer reaches the threshold level within the preset pulse rise times TW1 and TW2, which make the No.1 and No. 2 comparator timers detect no signal. In other words, if the input signal is smaller than the threshold level and the input signal does not continue for the specified time (TW1, TW2) then this input signal is not identified as a leakage current and there is no SCR drive signal from the leakage detector 3.

Since this kind of SCR drive signal does not exist in some frequency ranges, we obtain the circuit in Fig. 4 with the current sensing frequency characteristics comprising the circuit in Fig. 1 and the operating characteristics in Figs. 2 and 3.

Generally, the cutoff frequency in the filter circuit or the frequency f_c having an abrupt rise is shown by:

$$f_c = 1 / 2 \pi CR \text{ ---- (1)}$$

Here, $2 \pi CR$ is a time set by the time constant CR. The specified time TW is set based on the time constant determined by capacitance of the IC with externally attached capacitor, so that by substituting πCR with TW, a formula for the frequency with an abrupt rise is obtained as shown below.

$$f_c = 1 / (2 \times TW) \text{ ---- (2)}$$

(Here, TW is the larger one in TW1 and TW2.)

By setting the specified time of the No.1 and No. 2 comparator timers, current sensing frequency characteristic, i.e. largely flat up to a certain frequency and having an abrupt rise above the certain frequency as shown in Fig. 5.

This embodiment thus obtains the curve shown by D in Fig. 6 by combining the current sensing frequency characteristic of the primary LPF2 and the current sensing frequency characteristic of the leakage detector 3. In other words, the earth leakage protection device of this invention incorporates a current frequency sensing characteristic from commercial frequencies to 1 kHz, below the threshold curve C for ventricular fibrillation caused by electrical current as described in IEC479-2, in order to protect the human body from electrical shock. In the frequency range from 1kHz to 2 kHz, a ventricular fibrillation current is allowed that is large when compared to that at commercial frequencies, so the current frequency sensing characteristic has an abrupt rise in this range, thus fulfilling the both objects of protecting the human body from electrical shock and preventing equipment from undesirable cut out by malfunction.





WHAT IS CLAIMED IS:

1. An earth leakage protection device having a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value, wherein

said tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range and said current sensing frequency characteristic is set below a specified threshold value within the first frequency range, said current sensing frequency characteristic is set to make an abrupt increase in the second frequency range that exceeds the first frequency range, and said current sensing frequency characteristic is set to be substantially infinite at all frequencies within a third frequency range that exceeds the second frequency range.

2. An earth leakage protection device having a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value, wherein

said tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range and said current sensing frequency characteristic is set below a specified threshold value within the first frequency range in order to protect the human body from electrical harm,

said current sensing frequency characteristic is set to make an abrupt increase in the second frequency range that exceeds the first frequency range; and said current sensing frequency characteristic is set to be substantially infinite at all frequencies within a third frequency range that exceeds the second frequency range.

3. An earth leakage protection device having a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value, wherein

said tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range and said current sensing frequency characteristic is set to be below a specified threshold value within commercial frequencies to 1 kHz to protect the human body from electrical harm,

said current sensing frequency characteristic is set to make an abrupt increase in the second frequency range that exceeds 1 kHz and extends to 2 kHz; and said current sensing frequency characteristic is set to be substantially infinite at all frequencies within a third frequency range that exceeds the second frequency range.

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4. An earth leakage protection device having a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value, comprising

a low-pass filter disposed in said tripping signal generating means, and said low-pass filter having a frequency characteristic set to be below a specified threshold value within commercial frequencies to 1 kHz in order to protect the human body from electrical harm; and said current sensing frequency characteristic is set to make an abrupt increase in the second frequency range that exceeds 1 kHz and extends to 2 kHz.

5. An earth leakage protection device of claim 4, wherein the current sensing frequency characteristic of said low-pass filter is set to be substantially infinite at frequencies within the frequency range exceeding 2 kHz.

6. An earth leakage protection device having a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value, comprising

a low-pass filter disposed in said tripping signal generating means, said low-pass filter having a frequency characteristic set in such a manner that the impedance is arranged so as to increase along with an increase in frequency below a specified threshold value within commercial frequencies to 1 kHz in order to protect the human body against electrical harm in the first frequency range; and in the second frequency range that exceeds 1 kHz and extends to 2 kHz, the impedance is set to make an abrupt rise along with an increase in the frequency; and in the third frequency range exceeding 2 kHz, the impedance is set to be substantially infinite for all frequencies within this frequency range.



ABSTRACT

This invention relates to an earth leakage breaker with the purposes of eliminating undesirable cut out occurring due to line noise from stray capacitance in wiring at higher frequencies than that used commercially and also of protecting the human body against electrical shock.

The earth leakage breaker of this invention is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value; current sensing frequency characteristics of the leakage breaker are set at less than a specified threshold value of a particular frequency zone while values exceeding this particular frequency zone are in a dead zone for sensing leakage current.



FIG. 1

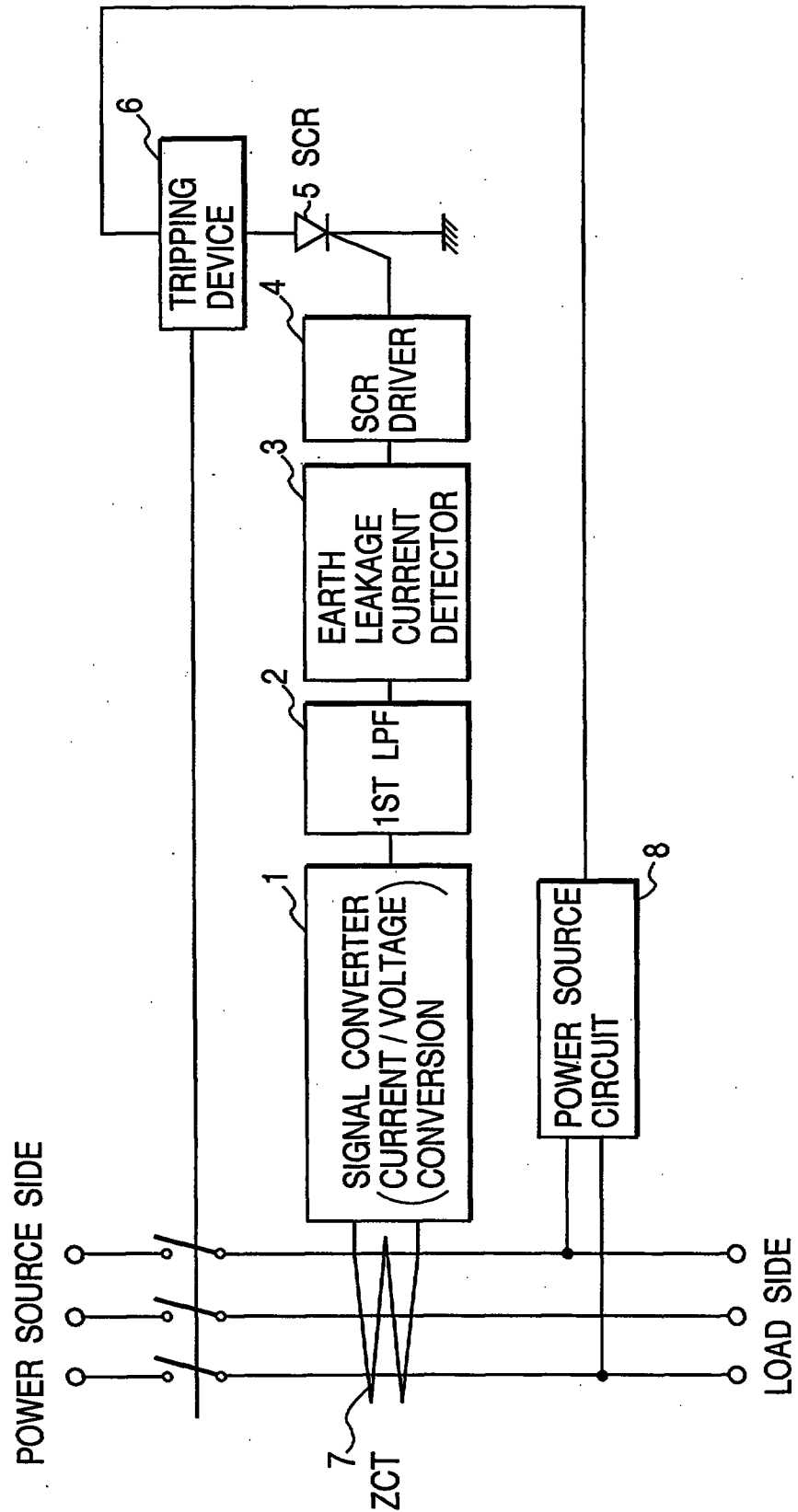
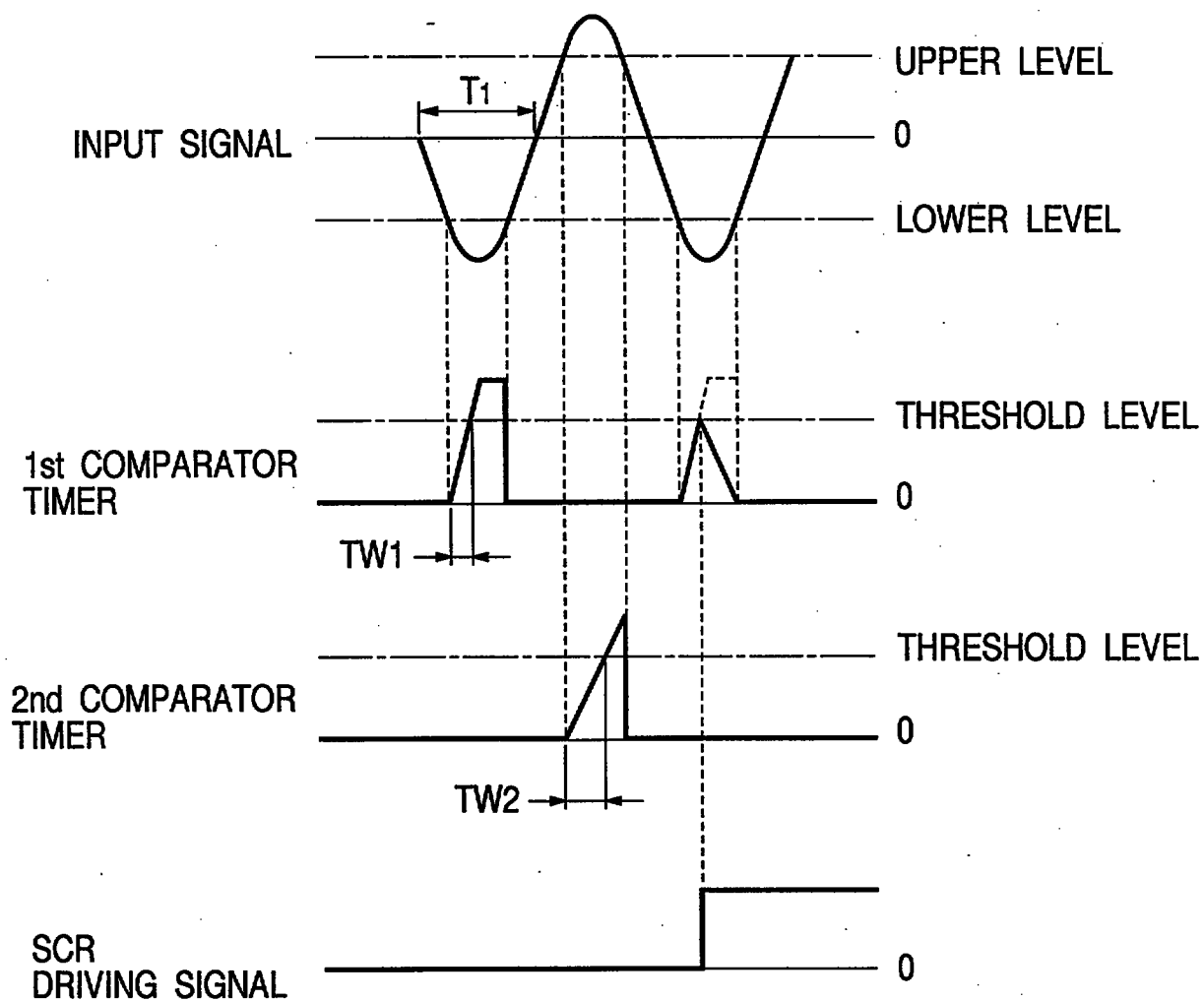
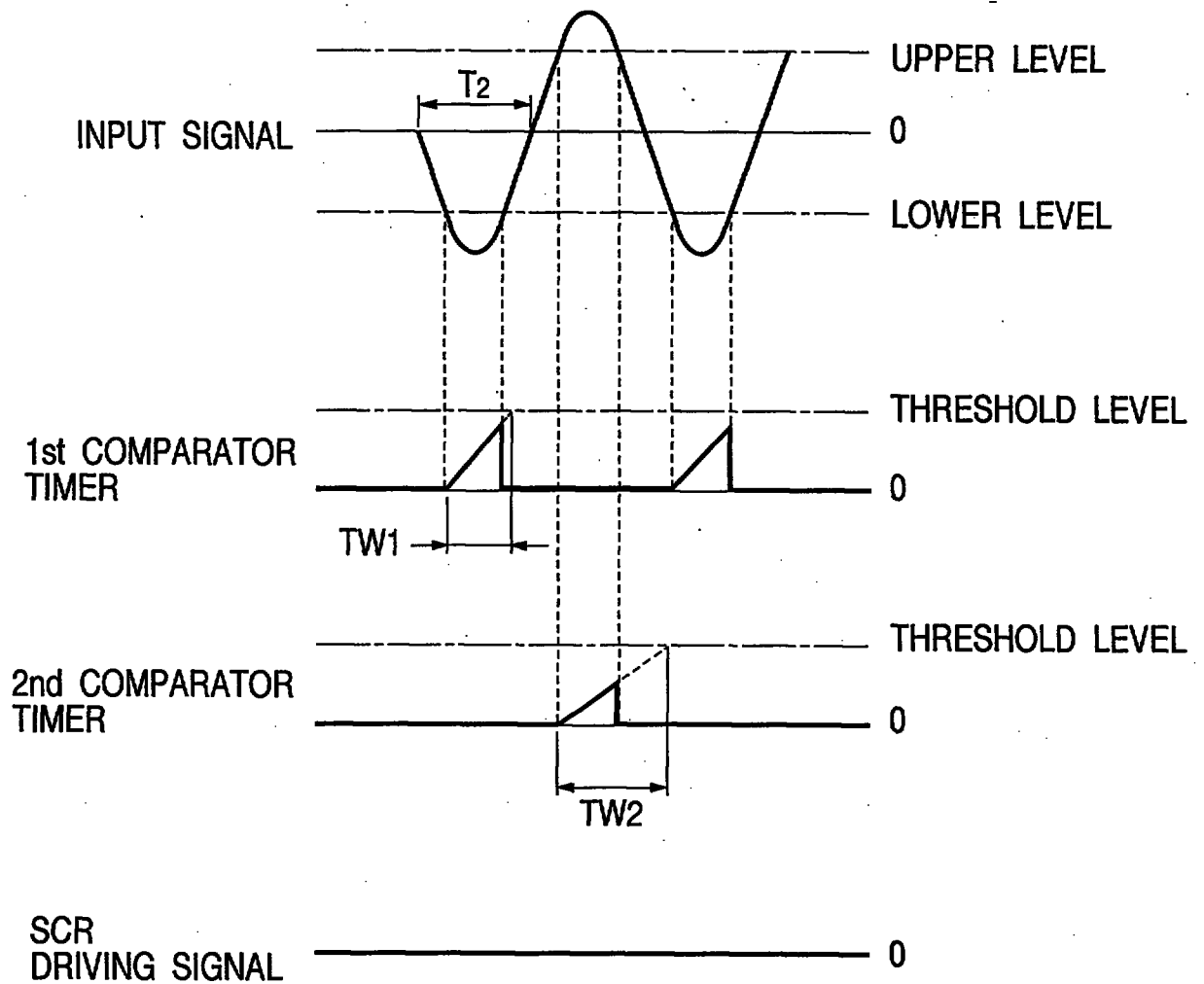


FIG. 2

(SCR DRIVING SIGNAL IS OUTPUT
AFTER DETECTING THREE WAVES
EACH HAVING A LARGER AMPLITUDE
THAN THE THRESHOLD LEVEL)

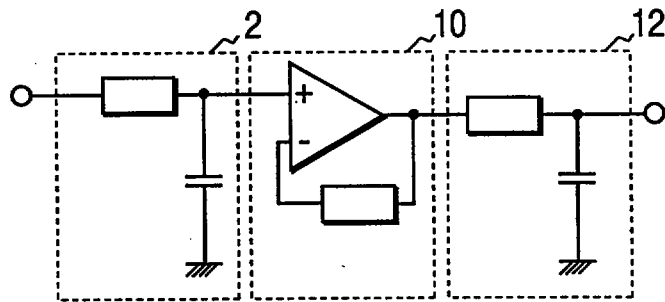
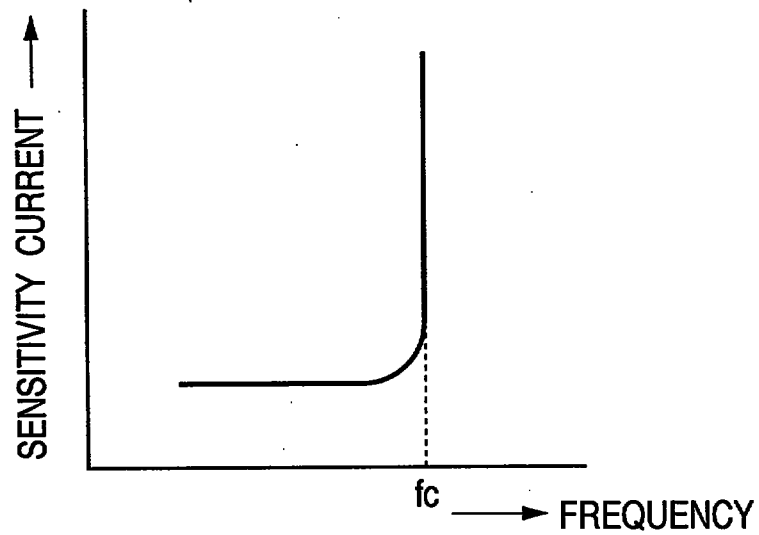


FIG. 3



(SCR DRIVING SIGNAL IS NOT
OUTPUT SINCE THE AMPLITUDE OF
RESPECTIVE WAVE DOES NOT
REACH THE THRESHOLD LEVEL)

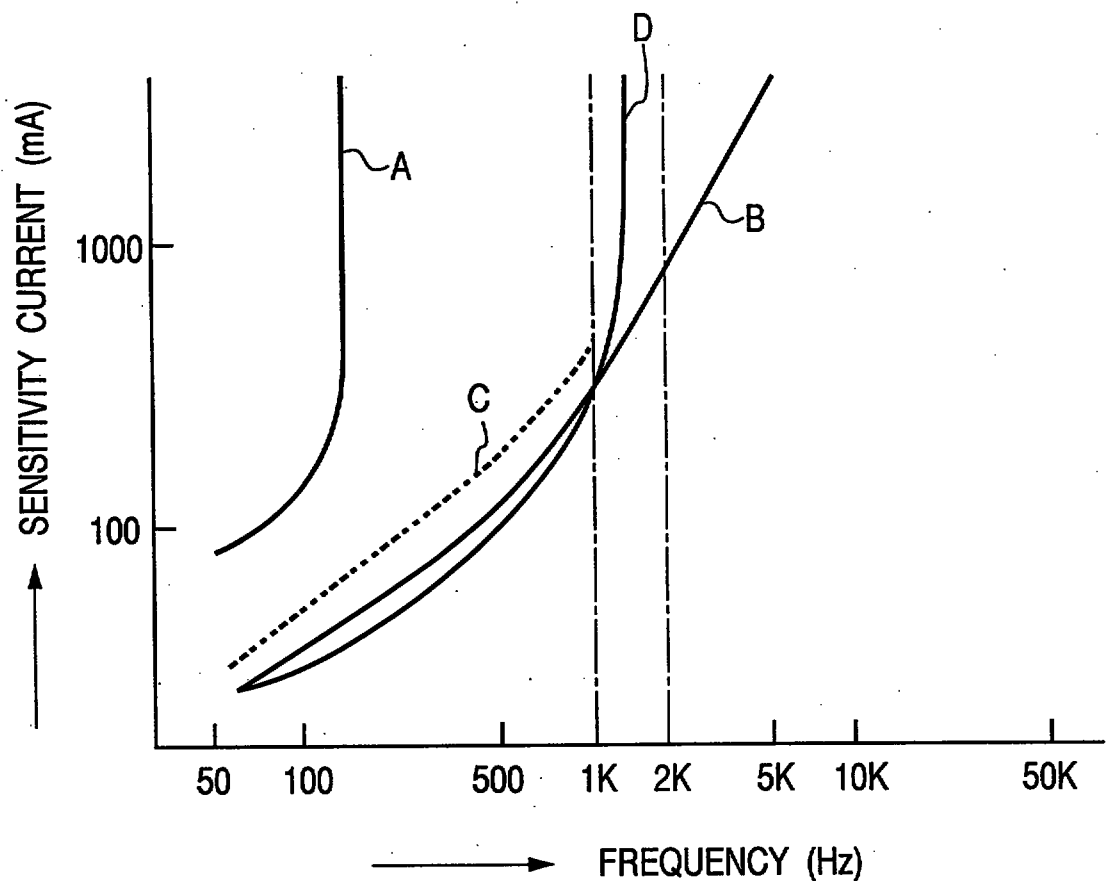


FIG. 4**FIG. 5**

$$f_c = \frac{1}{2 \times TW}$$

TW : LARGER VALUE IN TW1 AND TW2



FIG. 6

- A: CHARACTERISTIC OF CONVENTIONAL DELAYED TYPE
B: CHARACTERISTIC OF CONVENTIONAL HIGH-SPEED TYPE
C: THRESHOLD VALUE OF VENTRICULAR FIBRILLATION IN IEC 479-2
D: CHARACTERISTIC OF HIGH-SPEED TYPE IN THIS EMBODIMENT



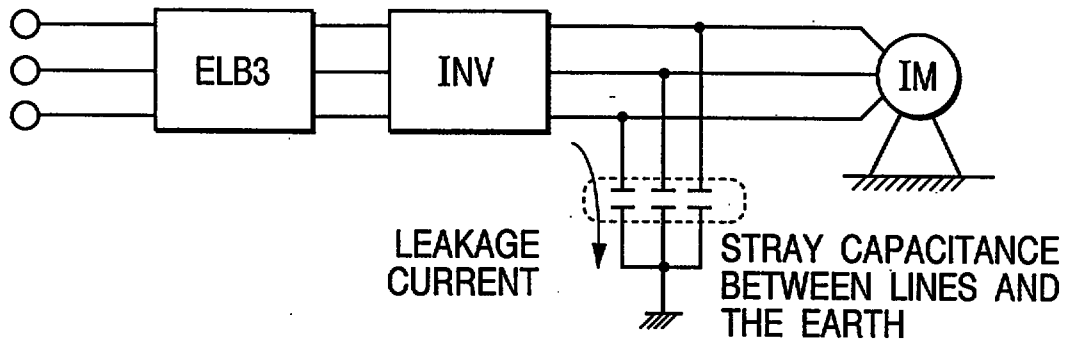
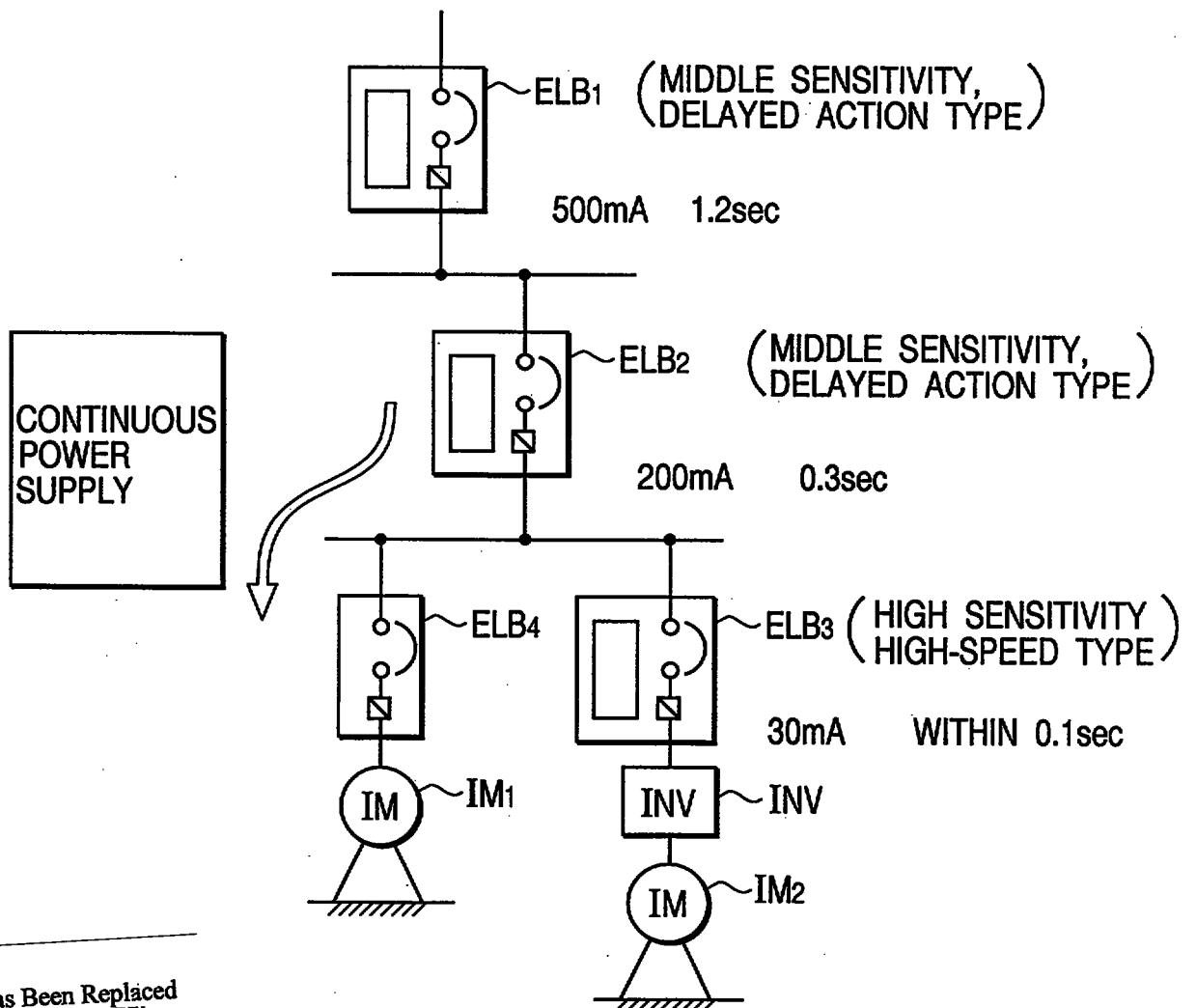
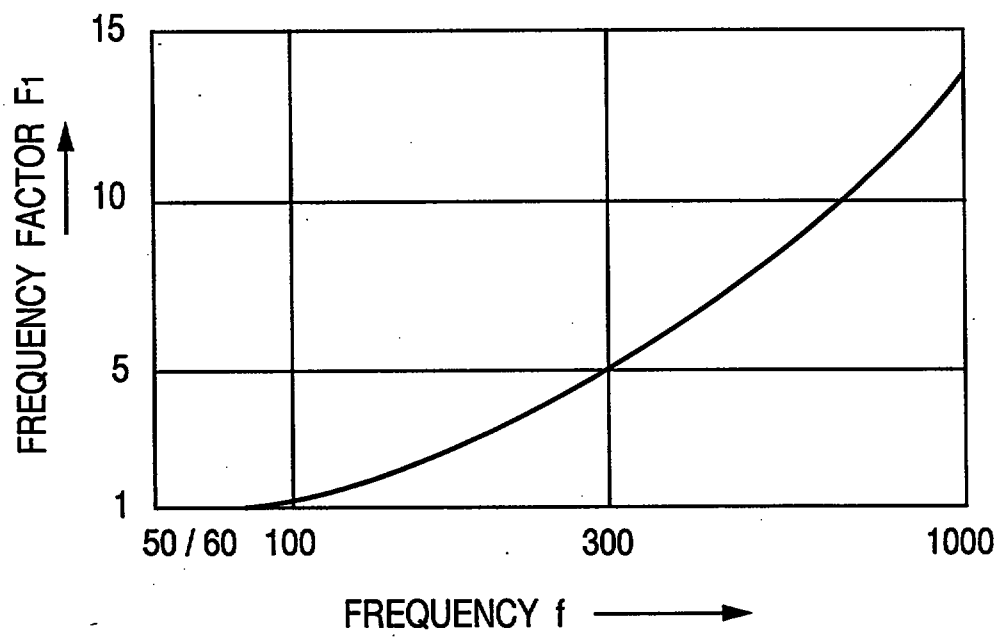
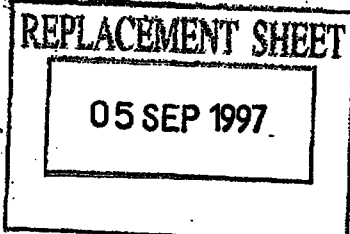
FIG. 7**FIG. 8**

FIG. 9

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REPLACEMENT SHEETS SG

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EARTH LEAKAGE-CURRENT PROTECTION DEVICE

BACKGROUND OF THE INVENTION

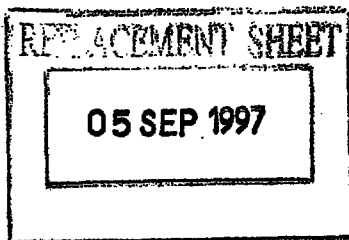
This invention relates to an earth leakage breaker having objects of protecting the human body from electrical shock caused by earth leakage current in ranges higher than commercial frequencies and also having a current sensing characteristic that prevents accidental operation from occurring due to earth leakage current resulting from stray capacitance in the high frequency range. This invention is applicable not only to earth leakage breakers with make-or-break contacts to cut out power but also to such equipments without make-or-break contacts as earth leakage relays configured to detect earth leakage current and generate a tripping signal which is supplied to other switchgear.

Description of Related Art

Earth leakage breakers having the object of protecting the human body from electrical shock and preventing malfunction or unnecessary operation in the high frequency range are known in such conventional art as described in EP Publication EP0 464 516 A2.

This prior art is an earth leakage-current protection system comprised of a high sensitivity, high speed type earth leakage breaker (hereinafter high sensitivity ELB) and a middle sensitivity, delayed action type earth leakage breaker(hereinafter middle sensitivity ELB). The high sensitivity ELB of this earth leakage-current protection system has a current sensing frequency characteristic set lower than a threshold value (for instance, a threshold value defined by the International Electrotechnical Commission (IEC) 479-2) for protecting a human body from earth leakage current in ranges exceeding commercial frequencies. The middle sensitivity ELB has a current sensing frequency characteristic with an abrupt rise near ranges exceeding commercial power frequencies.

In this conventional leakage protection system, the middle sensitivity ELB is connected in cascade in the upper stage of the high sensitivity ELB. When an earth leakage current having a frequency higher than commercial power frequencies flows through the circuit, and its magnitude exceeds the threshold value of the high sensitivity ELB, the high sensitivity ELB detects the earth leakage current and cuts off the circuit. As the current sensing frequency characteristic of the middle sensitivity ELB in the upper stage is determined so as to be raised abruptly at a frequency exceeding commercial power frequencies, the middle sensitivity ELB does not work at frequency ranges higher than the commercial frequencies. Therefore, an earth leakage current exceeding the threshold value and potentially harmful to the human body is cut out by the high sensitivity ELB in the lower stage, which prevents malfunction of the middle sensitivity ELB in the upper stage. On the other hand, the middle sensitivity ELB cuts out the



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circuit when electrical short circuit occurs to prevent further upper stages of the circuit from undesirable cut-out.

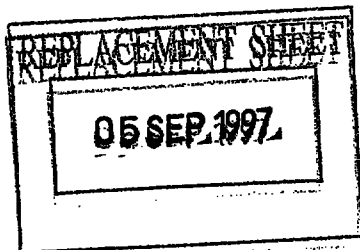
The drawbacks of the earth leakage-current protection system of the prior art are described below referring to Figs. 7, 8 and 9.

Figure 7 is a drawing showing the leakage current occurring due to stray capacitance between the circuit and the ground. Figure 8 shows the earth leakage-current protection system of the related art utilizing a high sensitivity ELB. Figure 9 is a graph showing the frequency factor of the current causing ventricular fibrillation versus frequency of the current described in IEC479-2. This graph indicates coefficients of the threshold value of the current causing ventricular fibrillation for respective frequency. For instance, the threshold value, compared to that at commercial frequency, becomes approximately fivefold at 300 Hz and increases continuously up to nearly fourteenfold at 1 kHz.

An example of a circuit including an inverter as a load (hereinafter inverter load) for the earth leakage breaker is shown in Fig. 7. Since a high frequency current flows in the inverter load, the earth leakage current derives most from current flowing through stray capacitance. Stray capacitance is greatly influenced by the condition of the wirings installed. When stray capacitance in the circuit is large, a large leakage current consequently flows through the capacity.

An example of protection coordination in a circuit having an inverter load is shown in Fig. 8. In this example, the high sensitivity, high speed type earth leakage breaker ELB3 (hereinafter high sensitivity breaker ELB3) is installed directly on the power supply side of the inverter INV that drives the motor IM2. The middle sensitivity, delayed action type earth leakage breaker ELB2 (hereinafter middle sensitivity breaker ELB2) is installed on the power supply side (i.e. upper stage) of the high sensitivity breaker ELB3. Another middle sensitivity, delayed action type earth leakage breaker ELB1 (hereinafter middle sensitivity breaker ELB1) is installed on the power supply side (i.e. upper stage) of middle sensitivity breaker ELB2. Thus the high sensitivity breaker ELB3 is installed between the load at its lower stage and the middle sensitivity breaker ELB2 at its upper stage. By setting such characteristics of high sensitivity breaker ELB3 and middle sensitivity breaker ELB2 as high sensitivity, high speed type and middle sensitivity, delayed action type respectively, high sensitivity breaker ELB3 is triggered first when a leakage current is detected in the circuit including the inverter load and breaks (cuts out) only the circuit where the leakage has occurred. Thus high sensitivity breaker ELB3 functions so as to prevent the other circuits from being cut out undesirably and it performs protection coordination of the circuit with the middle sensitivity breaker ELB2 installed on its upper stage.

The current sensing frequency characteristic of the leakage protection system is described referring to Fig. 6.



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In Fig. 6, A is a characteristic curve showing the current sensing frequency characteristic of the middle sensitivity breaker ELB2. The current sensing frequency characteristic of the middle sensitivity breaker ELB1 has the analogous curve to that of middle sensitivity breaker ELB2 and is located at a position somewhat to the upper left of that of middle sensitivity breaker ELB2. However the characteristic of middle sensitivity breaker ELB1 is not shown in the drawing in order to simplify the depiction. The current sensing frequency characteristic for the conventional high sensitivity breaker ELB3 is shown by the curve B.

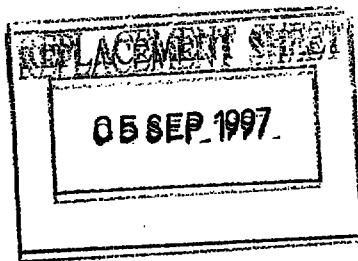
The current sensing frequency characteristic curve A for the middle sensitivity breaker ELB2 maintains a slight slope up to approximately 90 Hz and then increases with an abrupt rise. The current sensing frequency characteristic curve B for the high sensitivity breaker ELB3 maintains a gradual slope up to 1 kHz and then increases between 1 kHz and 10 kHz with a similar slope to threshold values of the ventricular fibrillation in IEC479-2. Since the high sensitivity breaker ELB3 is provided in order to protect the human body from such electrical harm as electrical shock, it has higher sensitivity for earth leakage current than that of the middle sensitivity breaker ELB2.

Generally, it is extremely difficult to specify the stray capacitance between a circuit and the ground. This brings about extreme difficulty in selecting equipment on the basis of the stray capacitance when installing an earth leakage protection device. Further, most current will act as noise current when it has frequencies involved in the high frequency region i.e., frequency regions higher than commercial power frequencies. These noise current have a tendency of flowing into the circuit path easily through the stray capacitance. Therefore, when making use of the current sensing frequency characteristic of the high-speed high-sensing leakage breaker in the high frequency region as described in EPO464516A2, the large drawback exists that undesirable operation occurs when noise current is detected due to the high sensitivity.

SUMMARY OF THE INVENTION

It is therefore an object of the invention in view of the above, to provide an earth leakage protection device that fulfills the purposes of protecting the human body from electrical shock caused by leakage current of high frequency and of preventing undesirable tripping from occurring in similar devices with an inverter load.

In order to achieve these objects the earth leakage protection device of this invention is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value, wherein



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the tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range. This current sensing frequency characteristic is set to be below a specified threshold value within the first frequency range, the current sensing frequency characteristic is set to make a sharp increase in the second frequency range which exceeds the first frequency range and the current sensing frequency characteristic is set to be substantially infinite at all frequencies within this frequency range, which exceeds the second frequency range.

Further, the ground leakage protection device of this invention is provided with a leakage current sensing means and a tripping signal issuing means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value of which;

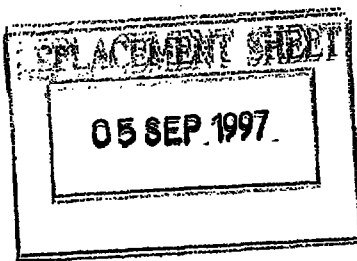
the tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range. This current sensing frequency characteristic is set to be below a specified threshold value within the first frequency range to protect the human body from harm. The current sensing frequency characteristic is set to make a sharp increase in the second frequency range which exceeds the first frequency range and the current sensing frequency characteristic is set to be essentially infinite at all frequencies within this frequency range, which exceeds the second frequency range.

Yet further, the earth leakage protection device of this invention is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value of which;

the tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range. This current sensing frequency characteristic is set to be below a specified threshold value from commercial frequencies to 1 kHz to protect the human body from electrical harm. The current sensing frequency characteristic is set to make a sharp increase in the second frequency range which exceeds 1 kHz and extends to 2 kHz. The current sensing frequency characteristic is set to be substantially infinite at all frequencies within this frequency range, which exceeds the second frequency range.

Even still further, the earth leakage protection device of this invention is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value of which;

the tripping signal generating means has a low-pass filter. The frequency characteristic of the low-pass filter is set to be below a specified threshold value within commercial frequencies to 1 kHz, in order to protect the human body from electrical harm. The current sensing frequency characteristic is set to make an abrupt increase in the second frequency range which exceeds 1 kHz and extends to 2 kHz.



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Yet still further, the earth leakage protection device of this invention is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value of which;

the tripping signal generating means has a low-pass filter. The frequency characteristic of the low-pass filter is set to be below a specified threshold value within commercial frequencies to 1 kHz, in order to protect the human body from electrical harm by arranging for the impedance to increase along with an increase in frequency. In the second frequency range which exceeds 1 kHz and extends to 2 kHz, the impedance is set to make an abrupt rise along with an increase in the frequency. In the frequency range exceeding 2 kHz, the impedance is set to be substantially infinite for all frequencies within this frequency range.

An earth leakage protection device of this invention can therefore be provided which fulfills the purposes of protecting the human body from electrical shock caused by leakage current of high frequency and of preventing undesirable tripping from occurring in similar devices with an inverter load.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram showing the configuration of the earth leakage protection device in one embodiment of this invention.

Figure 2 is timing charts showing sample operation of the earth leakage protection device in one embodiment of this invention.

Figure 3 is timing charts showing another sample operation of the earth leakage protection device in one embodiment of this invention.

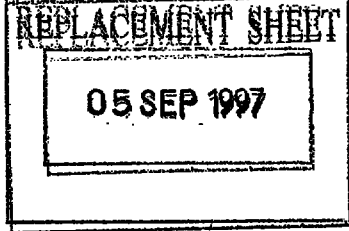
Figure 4 is a block diagram showing the structure of the low-pass filter in one embodiment of this invention.

Figure 5 is a graph showing the current sensing frequency characteristic in the earth leakage protection device in one embodiment of this invention.

Figure 6 is a graph comparing current sensing frequency characteristics in one embodiment of the earth leakage protection device of this invention with current sensing frequency characteristics in the related art.

Figure 7 is a descriptive drawing showing leakage current due to stray capacitance between the circuit and ground.

Figure 8 is a block diagram showing connections in the leakage protection system utilizing high-speed high sensing leakage breakers of the related art.



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Figure 9 is a graph showing factors relating to changes in size of current causing ventricular fibrillation versus frequency in IEC479-2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of this invention will now be described referring to Fig. 1 through Fig. 6.

The embodiment of this invention is applicable to electronic type earth leakage protection devices that amplify the output from the secondary of a zero-phase current transformer (hereinafter ZCT) to trigger a tripping device. The example in this embodiment is applied not only to an earth leakage breaker with make-or-break contacts but also to an equipment without make-or-break contacts such as leakage relay configured to detect an earth leakage current and generate a tripping signal to be supplied to other switchgear.

A block diagram showing the configuration of the earth leakage protection device of this embodiment is given in Fig. 1. Figure 2 is timing charts showing the sample operation of the earth leakage protection device in the embodiment of this invention. Figure 3 is another set of timing charts showing another example of operation in this embodiment. A block diagram showing the structure of the low-pass filter is given in Fig. 4. Figure 5 is a graph showing the current sensing frequency characteristic in the circuit operation in Figs. 2 and 3. The graph in Fig. 6 compares current sensing frequency characteristics in one embodiment of the earth leakage protection device of this invention with current sensing frequency characteristics in the device of the related art.

The earth leakage protection device of this embodiment is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected earth leakage current reaches a specified value.

The tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range. These frequency ranges are grouped into the first, second and third frequency ranges. Frequencies involved in the second range exceed those involved in the first range, and frequencies involved in the third range exceed those involved in the second range. The current sensing frequency characteristic is set to be below a specified threshold value within the first frequency range. The current sensing frequency characteristic is set to make an abrupt rise or increase in the second frequency range. The current sensing frequency characteristic is set to be substantially infinite at all frequencies within the third frequency range.

More specifically, the ZCT 7, as the leakage current sensing means, detects an imbalance in the currents flowing through the earth leakage breaker installed in the circuit path between the power source and the load. When earth leakage occurs, electrical currents get unbalanced and output current is induced

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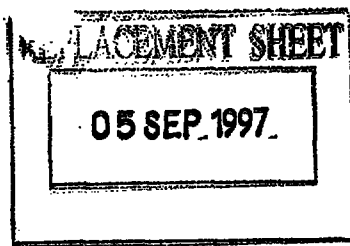
in the ZCT 7 by this unbalanced currents. This current output from the ZCT 7 is converted to an electrical voltage signal in a signal converter 1. This voltage signal is supplied to a leakage detector 3 by means of the primary low-pass filter (hereafter LPF) 2. The leakage detector 3 generates a tripping signal to an SCR drive means 4 when the leakage current reaches a specific value. Then this SCR drive means 4 supplies a signal to the gate of an SCR5. This signal turns on the SCR 5 and a tripping mechanism 6 is triggered. The tripping means opens the make-or-break contacts provided in the circuit path by the resultant mechanical action to cut out the circuit. Namely, the LPF 2 and the leakage detector 3 function as a tripping signal generating means. The power supply 8 supplies power to the signal converter 1, LPF 2, leakage detector 3, SCR drive means 4 and tripping device 6.

In this embodiment, the frequency ranges are; the first frequency range which is set to be from commercial frequencies (50/60 Hz) to 1 kHz, the second frequency range which is set to exceed 1 kHz and extend to 2 kHz, and the third frequency range which is set to exceed 2 kHz. These frequency ranges are set by the LPF2.

The frequency characteristic of the LPF 2 is set to be below a specified threshold value in the range from commercial frequencies to 1 kHz in order to protect the human body from harm, by setting the impedance to increase along with increases in frequency. In the second frequency range which exceeds 1 kHz and extends to 2 kHz, the impedance is set to make a sharp rise along with an increase in the frequency. In the second frequency range, in other words, all frequencies exceeding 2 kHz, the impedance is set to be substantially infinite.

This arrangement assigns a different current sensing frequency characteristic in the tripping signal generating means to the frequency ranges. The current sensing frequency characteristic of the earth leakage breaker is set to be below a specified threshold value within the first frequency range in order to protect the human body from electrical shock. The current sensing frequency characteristic is set to make an abrupt rise in the second frequency range. The current sensing frequency characteristic is set to be substantially infinite at all frequencies within the third frequency range.

The frequency ranges are grouped as described above for the following reasons. The carrier frequencies for inverters on the market have previously been established in a range from 1 kHz to 16 kHz so that a current sensing frequency characteristic are assigned below 1 kHz to respond at a leakage current below the threshold value for ventricular fibrillation as described in IEC479-2; a current sensing frequency characteristic with an abrupt rise in the frequency band exceeding 1 kHz and extending to 2 kHz; and a current sensing frequency characteristic substantially infinite at all frequencies included within the range exceeding 2 kHz. Therefore the current sensing characteristic in the earth leakage breaker of this embodiment is set to be infinite at frequencies greater than 2 kHz. Namely, this frequency range becomes



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a dead zone, which prevents the undesirable operation from occurring by noise current straying into the circuit due to stray capacitance.

In this embodiment, the primary filter LPF 2 is a filter having a similar characteristic of gain to that of the frequency characteristic of threshold value for ventricular fibrillation described in IEC479-2.

An ordinary CR filter shown in Fig. 4 can be used as the primary filter LPF2. The frequency characteristic of the primary LPF2 is set to be below a specified threshold value within commercial frequencies to 1 kHz, in order to protect the human body from such electrical harm as electrical shock. Signals passing through the LPF 2 are input to the leakage detector 3. Common commercially available ICs may be utilized as the leakage detector 3. A buffer 10 and a secondary LPF 12 may be provided between the primary LPF2 and the leakage detector 3 to improve noise tolerance. The LPF1 is set in such cases to cut frequencies higher than approximately 3 kHz.

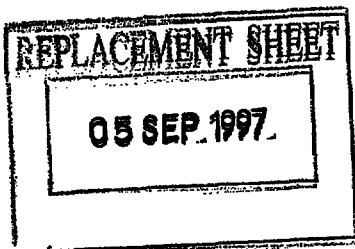
As shown in Fig. 2, the leakage detector 3 compares the upper and lower values of the input signal waveform of the half-wave length T1 with the threshold level. The No. 1 comparator timer (not shown in drawing) inside the leakage detector 3 contains the lower threshold level and outputs a positive pulse only when a leakage current is detected by an input signal waveform that reaches this lower threshold level. The rising time of the pulse from zero-level to the threshold level is defined as TW1 in this case.

In the same way, the No. 2 comparator timer (not shown in drawing) inside the leakage detector 3 contains the upper threshold level and outputs a positive pulse only when a leakage current is detected by an input signal waveform that reaches this upper threshold level. The rising time (hereinafter pulse rise time) of the pulse from zero-level to the threshold level is defined as TW2 in this case.

A positive pulse is output when an input pulse waveform is again input to the comparator timer.

The pulse rise times TW1 and TW2 can be set by changing the circuit constants, which is defined by filter capacitance and resistor values of the No.1 comparator timer and the No. 2 comparator timer installed in the leakage detector 3. The desired setting can be changed also in a digital type system by altering the counted value. In this embodiment, the timer is set by changing the filter capacitance contained in the timer circuit while a fixed threshold value has been set. When a commercially available IC is used as the leakage detector 3, the rise slope of the No.1 comparator timer and the No. 2 comparator timer is usually changed by altering the capacitance of the externally installed filter in order to set the time required to reach the timer threshold level.

Thus, this circuit is configured to generate an SCR drive signal regarding that a leakage current is detected, when three waveforms have been verified in the leakage detector 3, or only when the input signal



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has reached a minimum specified magnitude (threshold level) or the input signal has continued specified time (TW1 or TW2).

In Fig. 3 on the other hand, when a high frequency signal with a half-wavelength T2 ($T2 < T1$) is input to the leakage detector 3, output of neither of the No.1 comparator timer nor the No. 2 comparator timer reaches the threshold level within the preset pulse rise times TW1 and TW2, which make the No.1 and No. 2 comparator timers detect no signal. In other words, if the input signal is smaller than the threshold level and the input signal does not continue for the specified time (TW1, TW2) then this input signal is not identified as a leakage current and there is no SCR drive signal from the leakage detector 3.

Since this kind of SCR drive signal does not exist in some frequency ranges, we obtain the circuit in Fig. 4 with the current sensing frequency characteristics comprising the circuit in Fig. 1 and the operating characteristics in Figs. 2 and 3.

Generally, the cutoff frequency in the filter circuit or the frequency f_c having an abrupt rise is shown by:

$$f_c = 1 / 2 \pi CR \text{ ---- (1)}$$

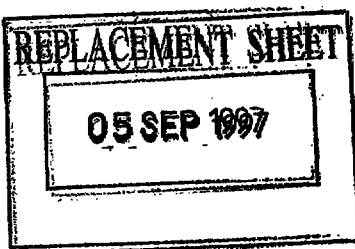
Here, $2 \pi CR$ is a time set by the time constant CR. The specified time TW is set based on the time constant determined by capacitance of the IC with externally attached capacitor, so that by substituting πCR with TW, a formula for the frequency with an abrupt rise is obtained as shown below.

$$f_c = 1 / (2 \times TW) \text{ ---- (2)}$$

(Here, TW is the larger one in TW1 and TW2.)

By setting the specified time of the No.1 and No. 2 comparator timers, current sensing frequency characteristic, i.e. largely flat up to a certain frequency and having an abrupt rise above the certain frequency as shown in Fig. 5.

This embodiment thus obtains the curve shown by D in Fig. 6 by combining the current sensing frequency characteristic of the primary LPF2 and the current sensing frequency characteristic of the leakage detector 3. In other words, the earth leakage protection device of this invention incorporates a current frequency sensing characteristic from commercial frequencies to 1 kHz, below the threshold curve C for ventricular fibrillation caused by electrical current as described in IEC479-2, in order to protect the human body from electrical shock. In the frequency range from 1kHz to 2 kHz, a ventricular fibrillation current is allowed that is large when compared to that at commercial frequencies, so the current frequency sensing characteristic has an abrupt rise in this range, thus fulfilling the both objects of protecting the human body from electrical shock and preventing equipment from undesirable cut out by malfunction.



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WHAT IS CLAIMED IS:

1. An earth leakage protection device having a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value , wherein

said tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range and said current sensing frequency characteristic is set below a specified threshold value within the first frequency range, said current sensing frequency characteristic is set to make an abrupt increase in the second frequency range that exceeds the first frequency range, and said current sensing frequency characteristic is set to be substantially infinite at all frequencies within a third frequency range that exceeds the second frequency range.

2. An earth leakage protection device having a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value , wherein

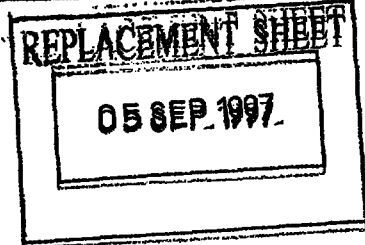
said tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range and said current sensing frequency characteristic is set below a specified threshold value within the first frequency range in order to protect the human body from electrical harm,

said current sensing frequency characteristic is set to make an abrupt increase in the second frequency range that exceeds the first frequency range; and said current sensing frequency characteristic is set to be substantially infinite at all frequencies within a third frequency range that exceeds the second frequency range.

3. An earth leakage protection device having a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value, wherein

said tripping signal generating means has a current sensing frequency characteristic which changes according to the frequency range and said current sensing frequency characteristic is set to be below a specified threshold value within commercial frequencies to 1 kHz to protect the human body from electrical harm,

said current sensing frequency characteristic is set to make an abrupt increase in the second frequency range that exceeds 1 kHz and extends to 2 kHz; and said current sensing frequency characteristic is set to be substantially infinite at all frequencies within a third frequency range that exceeds the second frequency range.



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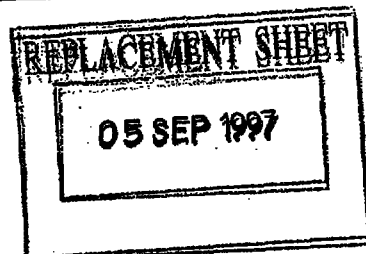
4. An earth leakage protection device having a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value, comprising

a low-pass filter disposed in said tripping signal generating means, and said low-pass filter having a frequency characteristic set to be below a specified threshold value within commercial frequencies to 1 kHz in order to protect the human body from electrical harm; and said current sensing frequency characteristic is set to make an abrupt increase in the second frequency range that exceeds 1 kHz and extends to 2 kHz.

5. An earth leakage protection device of claim 4, wherein the current sensing frequency characteristic of said low-pass filter is set to be substantially infinite at frequencies within the frequency range exceeding 2 kHz.

6. An earth leakage protection device having a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value, comprising

a low-pass filter disposed in said tripping signal generating means, said low-pass filter having a frequency characteristic set in such a manner that the impedance is arranged so as to increase along with an increase in frequency below a specified threshold value within commercial frequencies to 1 kHz in order to protect the human body against electrical harm in the first frequency range; and in the second frequency range that exceeds 1 kHz and extends to 2 kHz, the impedance is set to make an abrupt rise along with an increase in the frequency; and in the third frequency range exceeding 2 kHz, the impedance is set to be substantially infinite for all frequencies within this frequency range.



EARTH LEAKAGE-CURRENT PROTECTION DEVICE

ABSTRACT

This invention relates to an earth leakage breaker with the purposes of eliminating undesirable cut out occurring due to line noise from stray capacitance in wiring at higher frequencies than that used commercially and also of protecting the human body against electrical shock.

The earth leakage breaker of this invention is provided with a leakage current sensing means and a tripping signal generating means for emitting a trip signal in the circuit when the detected leakage current reaches a specified value; current sensing frequency characteristics of the leakage breaker are set at less than a specified threshold value of a particular frequency zone while values exceeding this particular frequency zone are in a dead zone for sensing leakage current.

Figure 1

FIG. 1

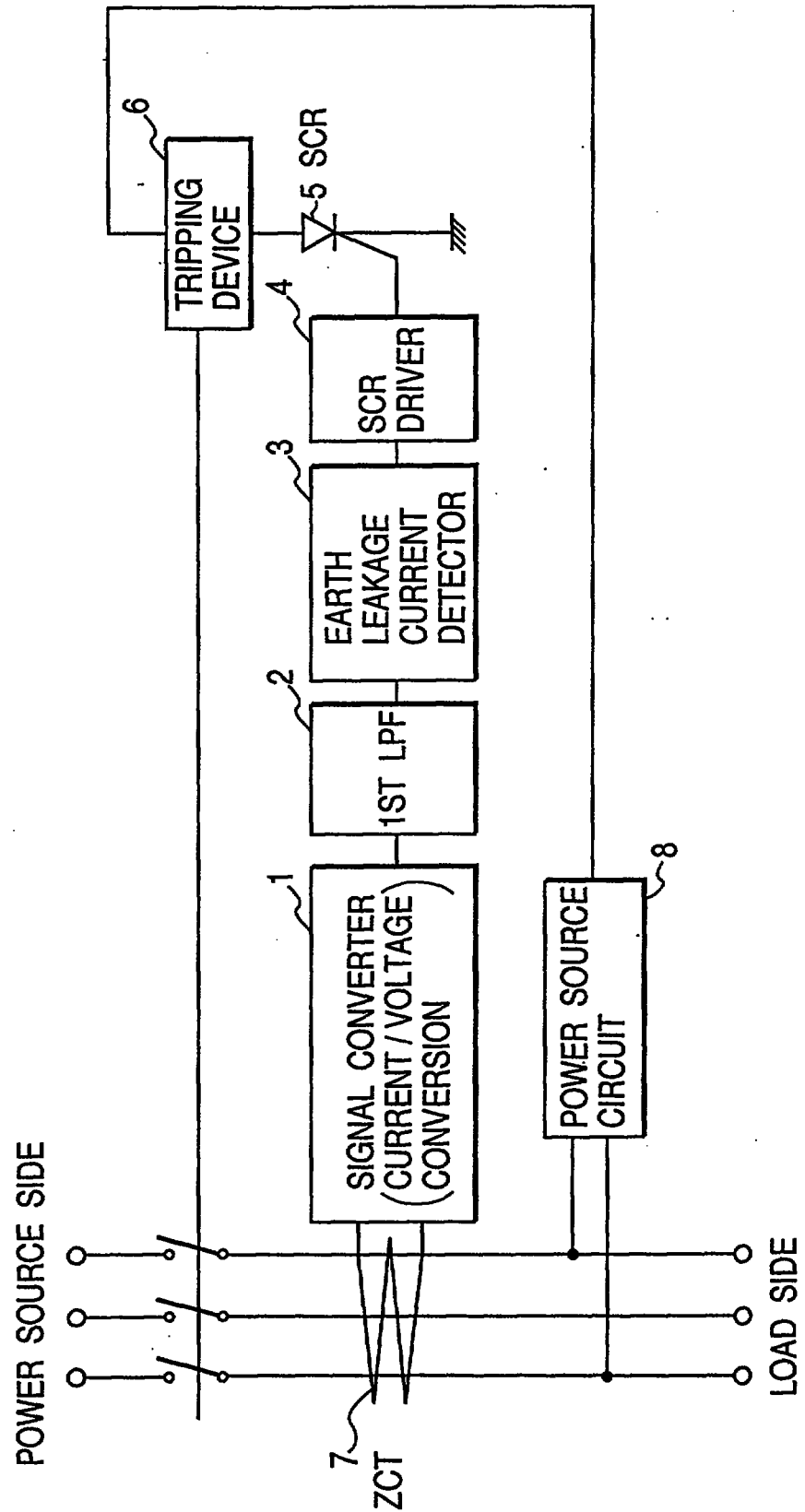
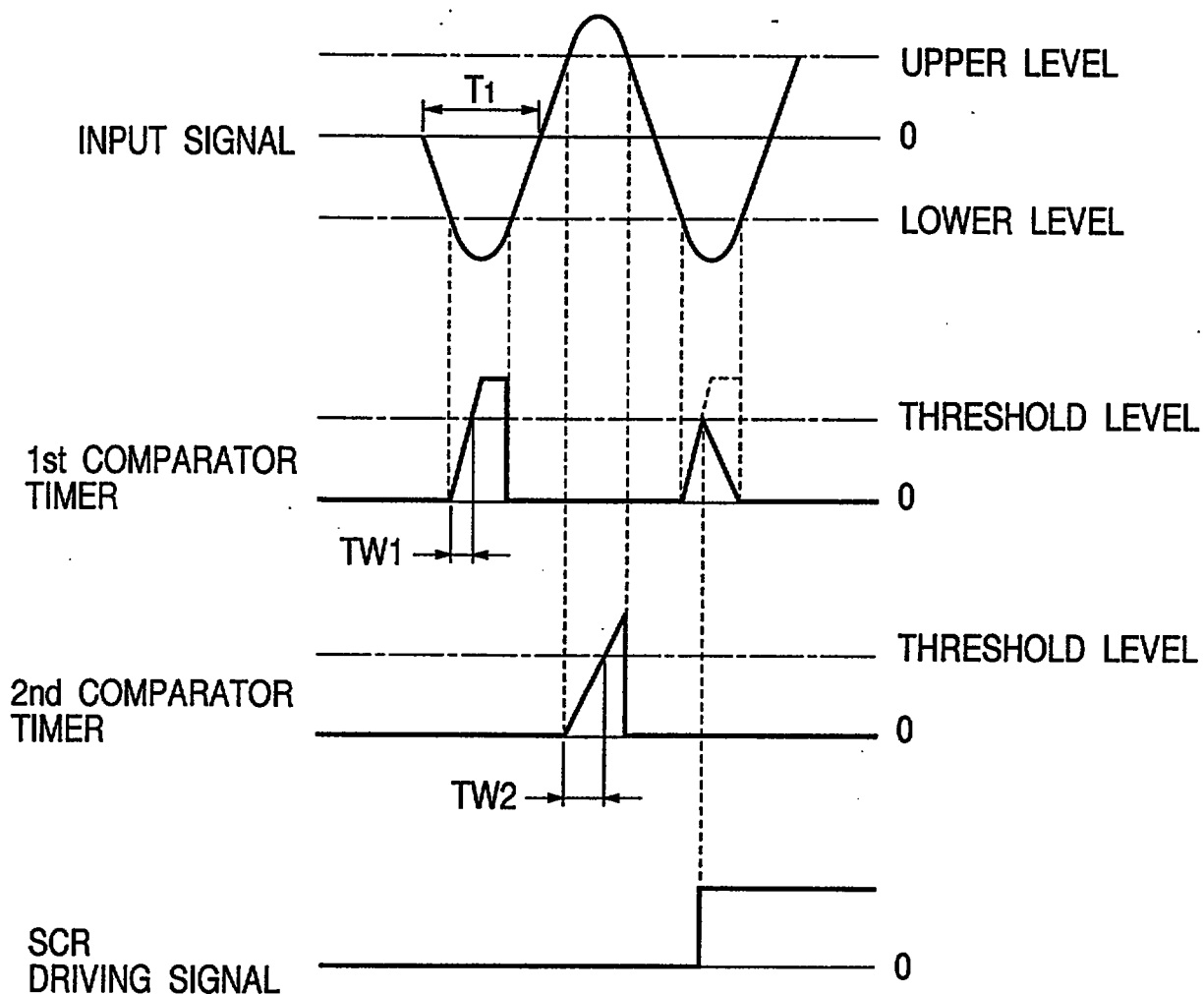
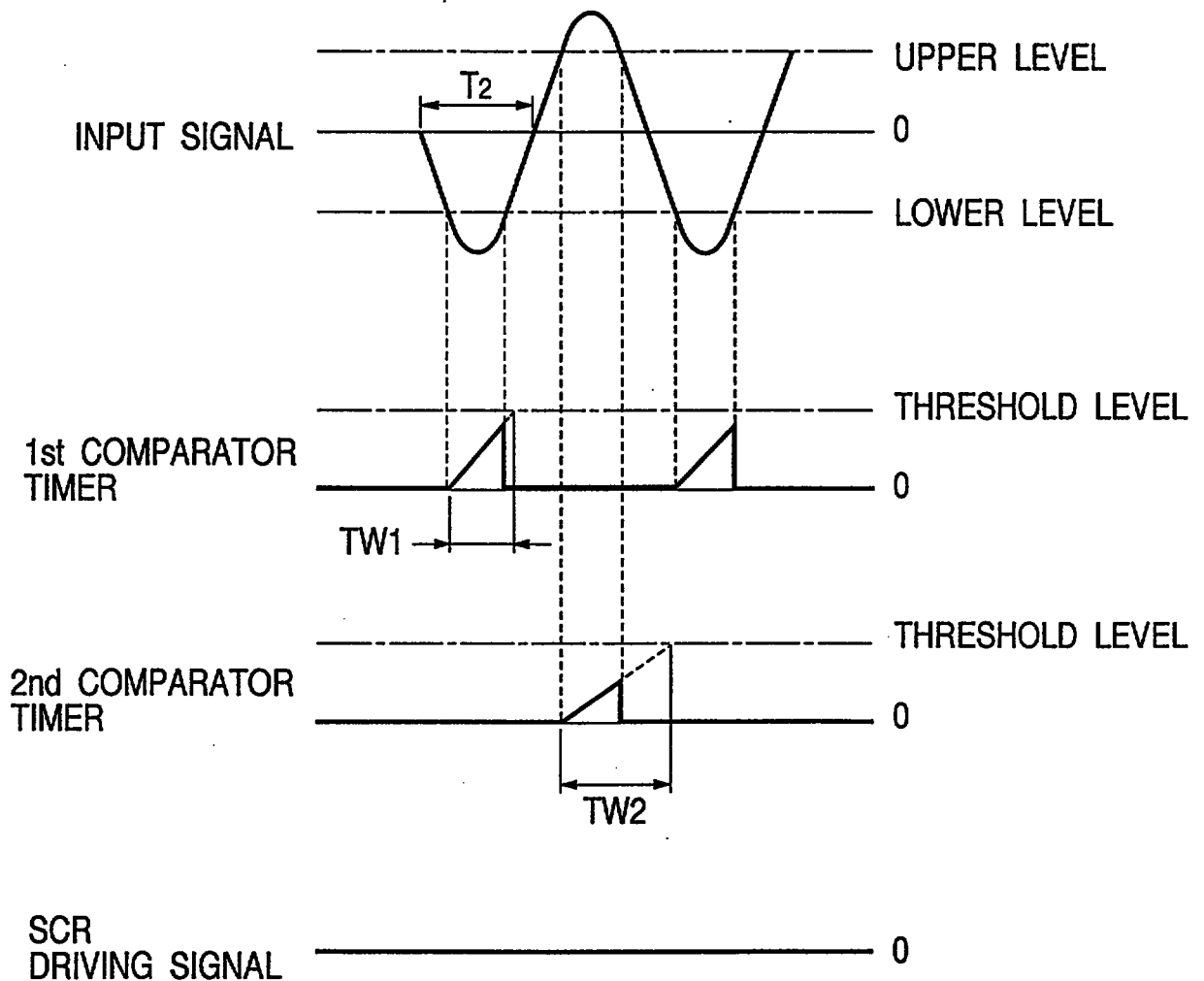


FIG. 2



(SCR DRIVING SIGNAL IS OUTPUT
AFTER DETECTING THREE WAVES
EACH HAVING A LARGER AMPLITUDE
THAN THE THRESHOLD LEVEL)

FIG. 3



(SCR DRIVING SIGNAL IS NOT
OUTPUT SINCE THE AMPLITUDE OF
RESPCTIVE WAVE DOES NOT
REACH THE THRESHOLD LEVEL)

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FIG. 4

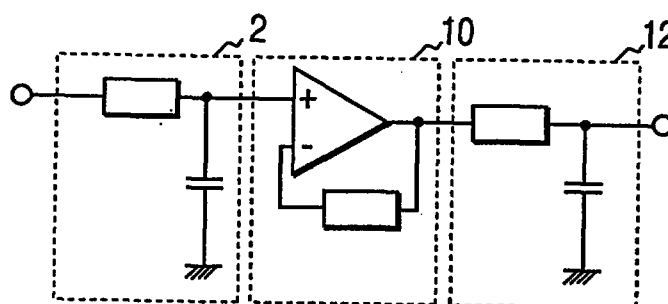
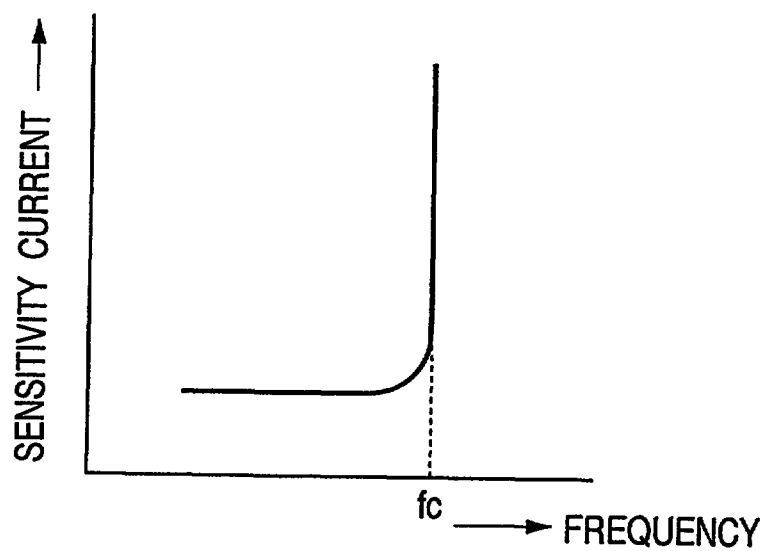


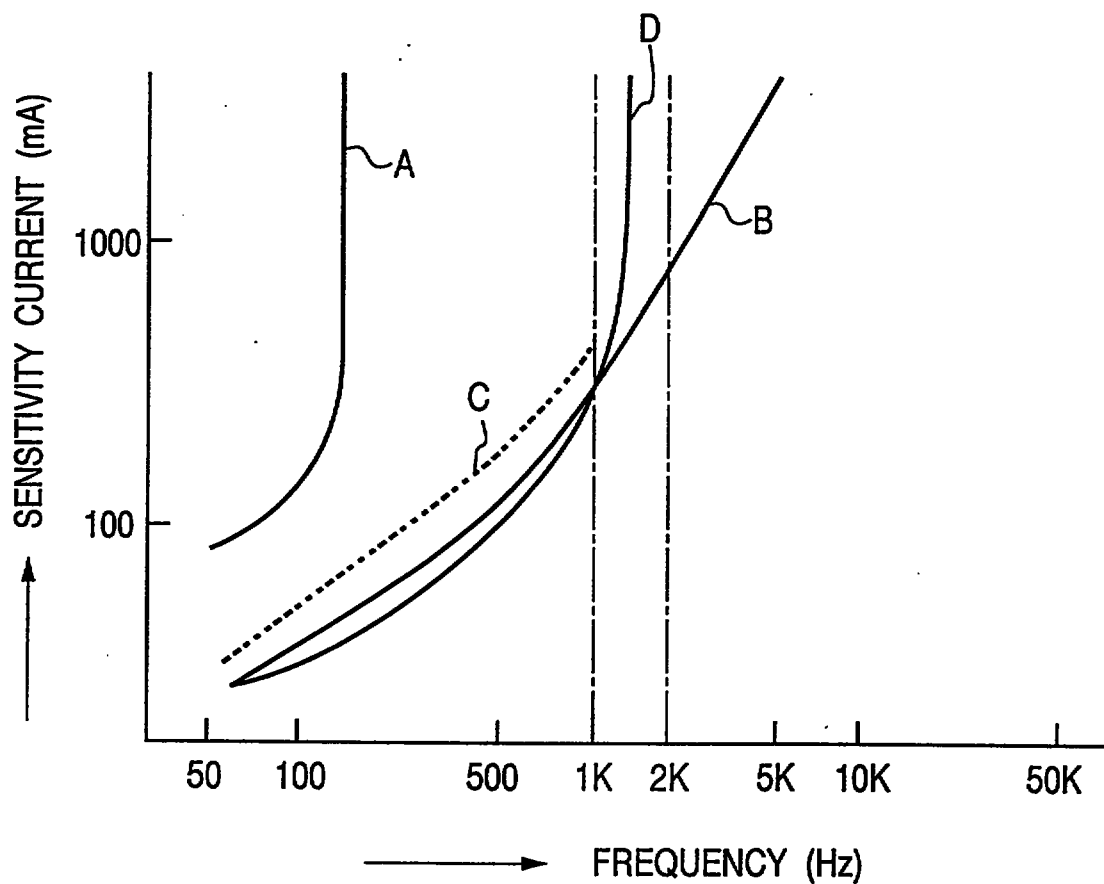
FIG. 5



$$f_c = \frac{1}{2 \times TW}$$

TW : LARGER VALUE IN TW1 AND TW2

FIG. 6



- A: CHARACTERISTIC OF CONVENTIONAL DELAYED TYPE
B: CHARACTERISTIC OF CONVENTIONAL HIGH-SPEED TYPE
C: THRESHOLD VALUE OF VENTRICULAR FIBRILLATION IN IEC 479-2
D: CHARACTERISTIC OF HIGH-SPEED TYPE IN THIS EMBODIMENT

FIG. 7

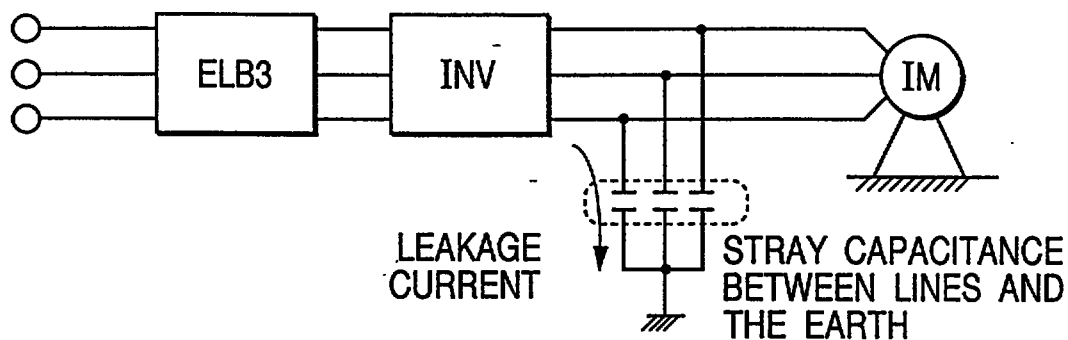


FIG. 8

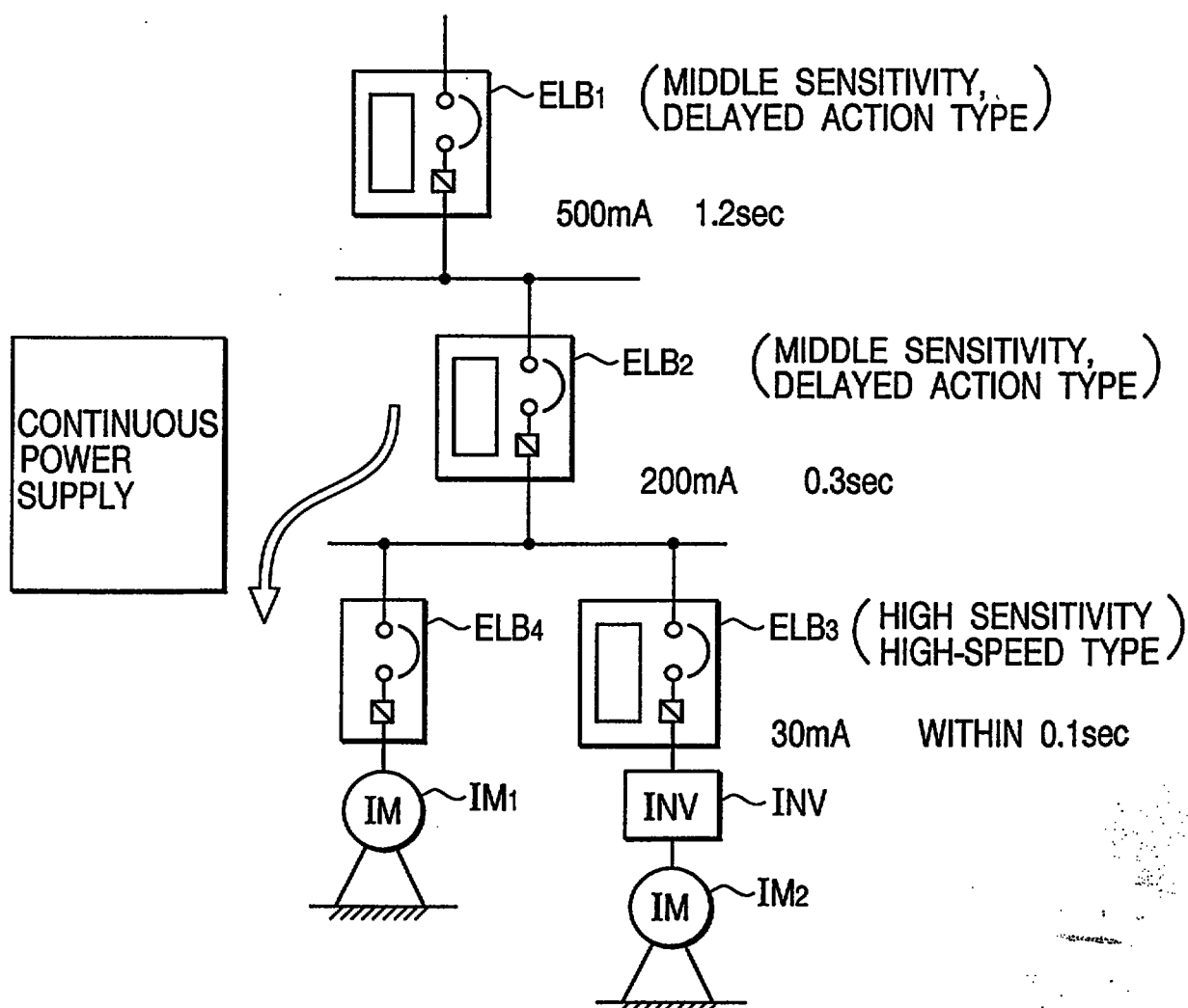


FIG. 9

