

PATENT SPECIFICATION

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(54) PROXIMITY DETECTOR

(71) We, MITSUBISHI DENKI KABUSHIKI KAISHA, a Japanese Company, of 2-3, Marunouchi 2-chome, Chiyoda-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a proximity detector for detecting a body through a change of electrostatic capacity, by which is meant electrical capacitance.

A proximity detector may be placed on the front edge of the door of an elevator, for example. When the door closes it detects an obstacle in the path of the door travelling path in contact-less manner, to reverse the mechanism to open the door or stop the closing operation of the door.

An exemplary circuit of this kind of proximity detector of the prior art is shown in Figure 1. In the figure, reference numerals (1) and (2) are a pair of antennae disposed longitudinally with a space therebetween along the front edge of an elevator door and have electrostatic capacities (3) and (4) with respect to earth. These antennae (1) and (2) have electrostatic capacities (6) and (7) to a shield plate (5) insulated therefrom. The antennae and the shield plate are disposed so as to satisfy the relation, electrostatic capacity (3) $\times$ electrostatic capacity (7) = electrostatic capacity (4) $\times$ electrostatic capacity (6).

Reference numeral (8) is an AC power source to supply voltage to the bridge circuit comprised of the capacities (3) and (4) and capacities (6) and (7). A transformer (9) is used to detect unbalance in the bridge circuit.

Normally, this bridge circuit is balanced and, when a body approaches the antennae (1) or (2), the approach of the body is generally asymmetrical with respect to the antennae (1) and (2) so that the bridge circuit produces an unbalance output signal. This is detected by a transformer (9), ampli-

fied by an AC amplifier (10), rectified by a rectifying circuit (11), and the output of the rectifying circuit is amplified by a DC amplifier (12) to drive a relay (13). Through the operation of the relay (13), closing operation of the door of the elevator is stopped or reversed to prevent the body from being nipped by the door.

In this apparatus, the electrostatic capacities (3) and (4) between the antennae (1) and (2), and earth are separate from the capacities (6) and (7) between the antennae (1) and (2), and the shield plate (5). Thus, there is the antennae (1) and (2) and insulation between earth and the shield plate and insulation between the shield plate (5) and the antennae (1) and (2).

During closing of the door, if one desires a sufficiently high sensitivity, the output voltage of the AC power source (8) must be large in order to prevent erroneous operation since sensitivity may be affected due to changes in characteristics of parts used in the amplifier and the like.

Even if the capacitances of the electrostatic capacities (3), (4), (6) and (7) forming respective bridge arms of the bridge circuit are balanced, a slight dielectric loss tangent ($\tan \delta$) produces a phase difference of the voltage induced in the antennae (1) and (2), and a phase unbalance voltage appears at the output of the detecting transformer (9). Thus, it is difficult to sufficiently increase the sensitivity of detection during the door closing.

With a view to overcoming the above-mentioned disadvantages, the present invention has an object to provide a proximity detector of simple assembly, elimination of the phase unbalance voltage and high sensitivity.

According to the present invention, there is provided a proximity detector comprising: a pair of antennae disposed along the front edge of a door with a space therebetween, the antennae having electrostatic capacities to earth; a coil for each antenna connected

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so as to constitute a series resonant circuit with the electrostatic capacitance of the respective antenna to earth; an AC power source for supplying voltages to said series resonant circuits; rectifying circuits for rectifying the voltages produced in said antennae; and a differential amplifier circuit for amplifying any difference between the outputs of said rectifying circuits.

The present invention will be better understood from the following description taken in connection with Figures 2 to 4 of the accompanying drawings, in which like reference characters refer to like parts or similar parts, and in which:—

Figure 2 shows a circuit diagram of an embodiment of a proximity detector according to the present invention;

Figure 3 shows the frequency characteristic curves of the series resonance circuits of Figure 2; and

Figure 4 shows a circuit diagram of another embodiment of the present invention.

In Figure 2, antennae (1) and (2) are connected to an AC power source (8), through coils (15) and (16). One end of the AC power source (8) is connected to earth. A balancing variable capacitor (17) is connected between antennae (2) and earth. Reference numerals (18) and (19) designate rectifying circuits which convert an AC voltage appearing at the antennae (1) and (2) into a DC voltage. A differential amplifier (20) amplifies the difference voltage between the DC outputs of the rectifying circuits (18) and (19).

The sum of the electrostatic capacity (3) between the antenna (1) and earth and another electrostatic capacity (6) between the antenna (1) and the shield plate (5), forms together with the coil (15), a series resonance circuit. Similarly, the sum of the capacity (4) between the antenna (2) and earth, a capacity (7) between the same and the shield plate (5) and a variable capacitor (17), forms, together with the coil 16, a series resonance circuit.

The variable capacitor (17) is so adjusted that these resonance circuits have much the same resonance frequencies. As shown in Figure 3 the frequency characteristic of each series resonance circuit is indicated by a curve (21) and the frequency f_0 of the AC power source (8) is set up on the steep slope portion of the characteristic curve. Thus, because of use of the series resonance circuits, an AC voltage appearing on each of the antennae (1) and (2) is very large with respect to the output voltage of the AC power source (8). The output voltage at the antennae is converted by the rectifying circuits (18) and (19) into DC voltages which

in turn are applied to the differential amplifier (20) where the rectified outputs are differentially amplified. With no body present near the antennae (1) and (2) the variable capacitor (17) is so adjusted that the amplitudes of the AC voltages appearing on the antennae (1) and (2) are equal. As a result, the unbalance voltage due to a slight phase difference of the voltages on the antennae (1) and (2) does not appear at the output of the differential amplifier circuit (20). When a body is present near the antenna (1) or (2) and the earth electrostatic capacity increases, the resonance characteristic curve (21) of the respective series resonance circuit shown in Figure 3 shifts to another resonance characteristic curve (22) of lower frequencies. At this time, the output voltage appearing at the respective antenna (1) or (2) at the frequency f_0 of the AC power source in Figure 2 increases by ΔV , compared to that when the antenna (1) or (2) does not detect the body.

Since a steep portion of the resonance curve is used, even if the rate of increase of the earth electrostatic capacities by object detection is small with respect to the sum of the earth electrostatic capacities of the antennae (1) and (2), or in other words the capacitance deviation is a small part of the total, it is possible to obtain sufficiently large change of voltage.

The AC voltages at the respective antennae due to the presence of an object are converted by the rectifying circuits (18) and (19) into DC voltages of which the difference is amplified by the differential amplifier (20) to drive the relay (13). The relay (13) stops or reverses the closing operation of the elevator door to prevent the body from being nipped by the door.

Figure 4 shows another embodiment in which the present invention is applied to a two-panel door, namely a door having two panels which meet centrally. In the figure, (23) and (24) designate detectors of the proximity detector each including antennae (1) and (2), shield plate (5), variable capacitor (17), coils (15) and (16), and rectifying circuits (18) and (19). Reference numeral (20a) designates adder/subtractor amplifier circuit. The detectors (23) and (24) are mounted on the two-panels respectively. The adder/subtractor amplifier circuit (20a) amplifies the sum of (a) the difference between the rectified outputs of the detector (23) and (b) the difference between the rectified outputs of the detector (24). In this way, the example has an ability to detect bodies on the front edges of the respective panels.

Only two antennae (1) and (2) are illustrated in each detector of Figure 2 and Figure 4. However, a plurality of antennae

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connected in parallel and longitudinally spaced may be used in place of each antenna. In Figures 2 and 4, only one of the antennae (1) and (2) is provided with the
5 variable capacitor (17) for unbalance adjustment which is inserted between the antenna and earth. Variable capacitors may be used for both the antennae (1) and (2). The frequency of the AC power source (8) may be
10 set up on the steep portion of the resonance characteristic curve at the high frequency side.

15 As described above, the present invention is constructed such that series resonance circuits are formed by coils connected to the antennae, voltages produced on the antennae are rectified and amplified and the movement of the door is controlled by the
20 output of the amplified output. Therefore, the detector produces a large output, with a small AC input voltage there-to. Additionally, there is eliminated unbalance voltage due to a slight phase difference so
25 that a very high sensitivity of detection may be obtained. Further, there is no insulation between the antenna shield plate and ground and therefore the apparatus may be easily mounted on the door.

30 WHAT WE CLAIM IS:—

1. A proximity detector comprising: a pair of antennae disposed along the front edge of a door with a space therebetween,
35 the antennae having electrostatic capacities to earth; a coil for each antenna connected

so as to constitute a series resonant circuit with the electrostatic capacitance of the respective antenna to earth; an AC power source for supplying voltages to said series resonant circuits; rectifying circuits for rectifying the voltages produced in said antennae; and a differential amplifier circuit for amplifying any difference between the
40 outputs of said rectifying circuits.

2. A proximity detector as claimed in Claim 1 wherein the door has a movement control mechanism which responds to the output of the differential amplifier.

3. A proximity detector according to Claim 1 wherein a variable capacitor is connected between one of the antennae and earth to adjust the amplitude of the AC voltage appearing on the antennae.

4. A proximity detector according to Claim 1 wherein a pair of coils, the electrostatic capacities and the rectifying circuits connected in series are provided on each panel of a two-panel door and an adder/subtractor amplifier circuit is fed with the
60 outputs from the rectifier circuits.

5. A proximity detector substantially as hereinbefore described with reference to Figures 2 and 3 or Figure 4 of the accompanying drawings.

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connected in parallel and longitudinally spaced may be used in place of each antenna. In Figures 2 and 4, only one of the antennae (1) and (2) is provided with the variable capacitor (17) for unbalance adjustment which is inserted between the antenna and earth. Variable capacitors may be used for both the antennae (1) and (2). The frequency of the AC power source (8) may be set up on the steep portion of the resonance characteristic curve at the high frequency side.

As described above, the present invention is constructed such that series resonance circuits are formed by coils connected to the antennae, voltages produced on the antennae are rectified and amplified and the movement of the door is controlled by the output of the amplified output. Therefore, the detector produces a large output, with a small AC input voltage there-to. Additionally, there is eliminated unbalance voltage due to a slight phase difference so that a very high sensitivity of detection may be obtained. Further, there is no insulation between the antenna shield plate and ground and therefore the apparatus may be easily mounted on the door.

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4. A proximity detector according to Claim 1 wherein a pair of coils, the electrostatic capacities and the rectifying circuits connected in series are provided on each panel of a two-panel door and an adder/subtractor amplifier circuit is fed with the outputs from the rectifier circuits.

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