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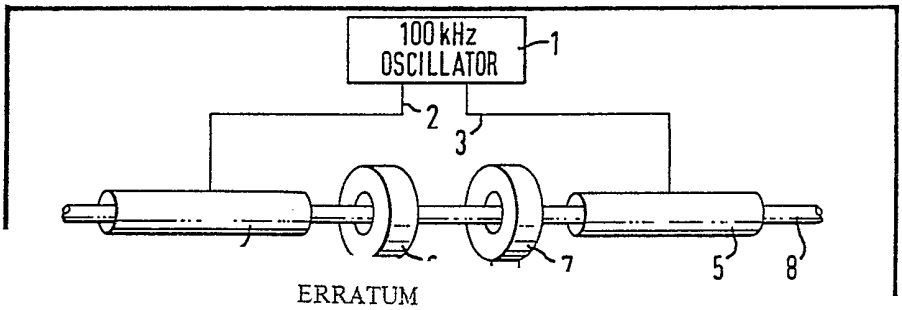
(54) Detecting Fault in Insulated Electric Cable

(57) Apparatus and a method for detecting a fault in an insulated electric cable with a spiral electrical conductor are disclosed. The cable (8) is passed through a pair of spaced-apart metal tubes (4, 5), each of which is connected to a respective side (2 or 3) of a balanced output of an oscillator (1). Between the tubes there is a pair of spaced-apart matched coils (6, 7) through which the cable passes, the coils sensing magnetic flux due to alternating current (I) flowing along the conductor (11) of the cable due to capacitive coupling via the tubes. The output of each coil is applied to an amplifier (12 or 13), a filter (14 or 15) and a signal level detector (16 or 17), each detector producing a DC output signal level. The levels produced are compared in a comparator (18) and if the latter detects a difference between the signal levels it compares greater than a certain amount (indicating a discontinuity in the conductor of the cable or a variation in pitch in the conductor of the cable greater than a certain amount, an audible alarm (21) is activated and a marker (22) marks the cable. The levels produced by the detectors are monitored by a level meter (19) and a deviation meter (20) monitors the difference between the signal levels compared by the conparator.



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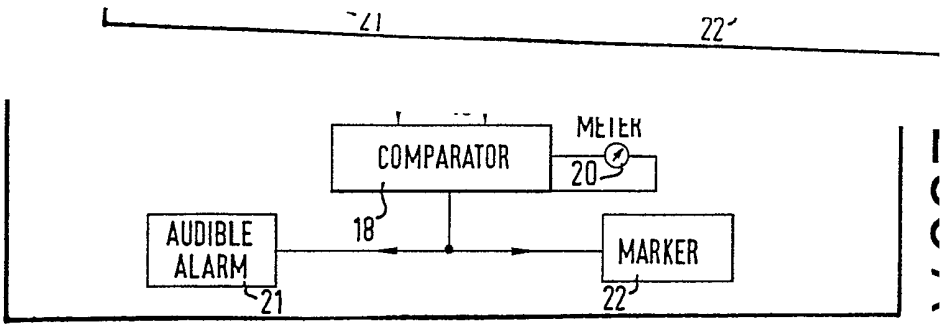

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(54) **Detecting Fault in Insulated Electric Cable**

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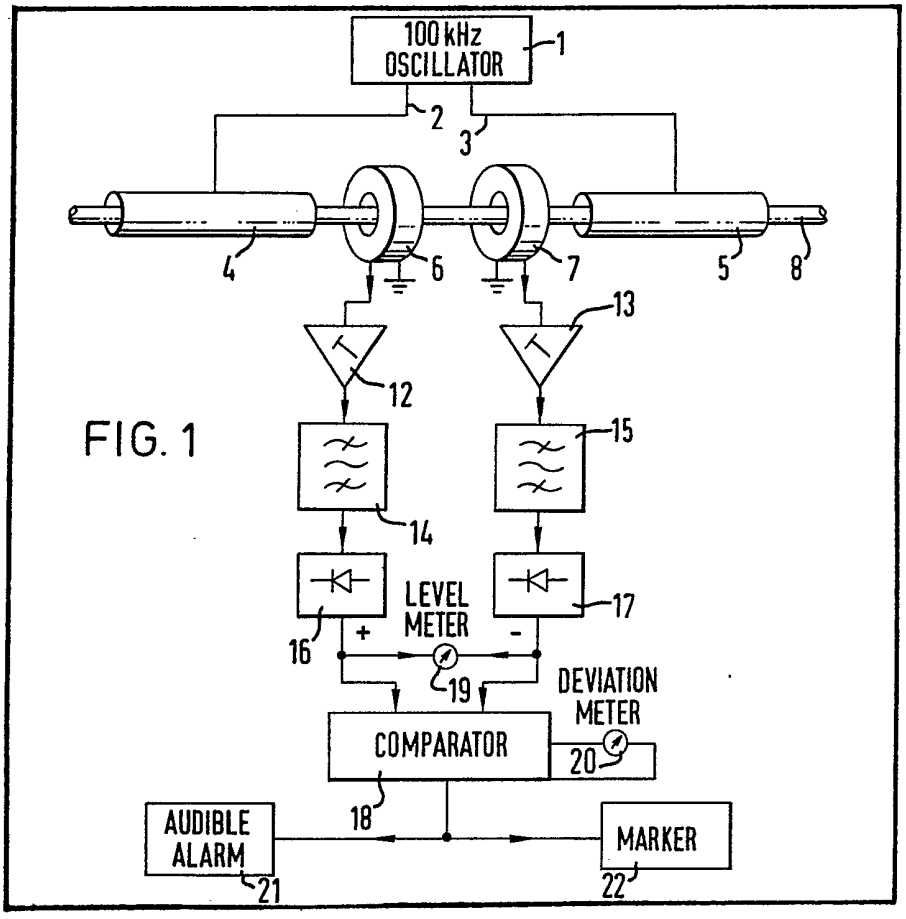

FIG. 1

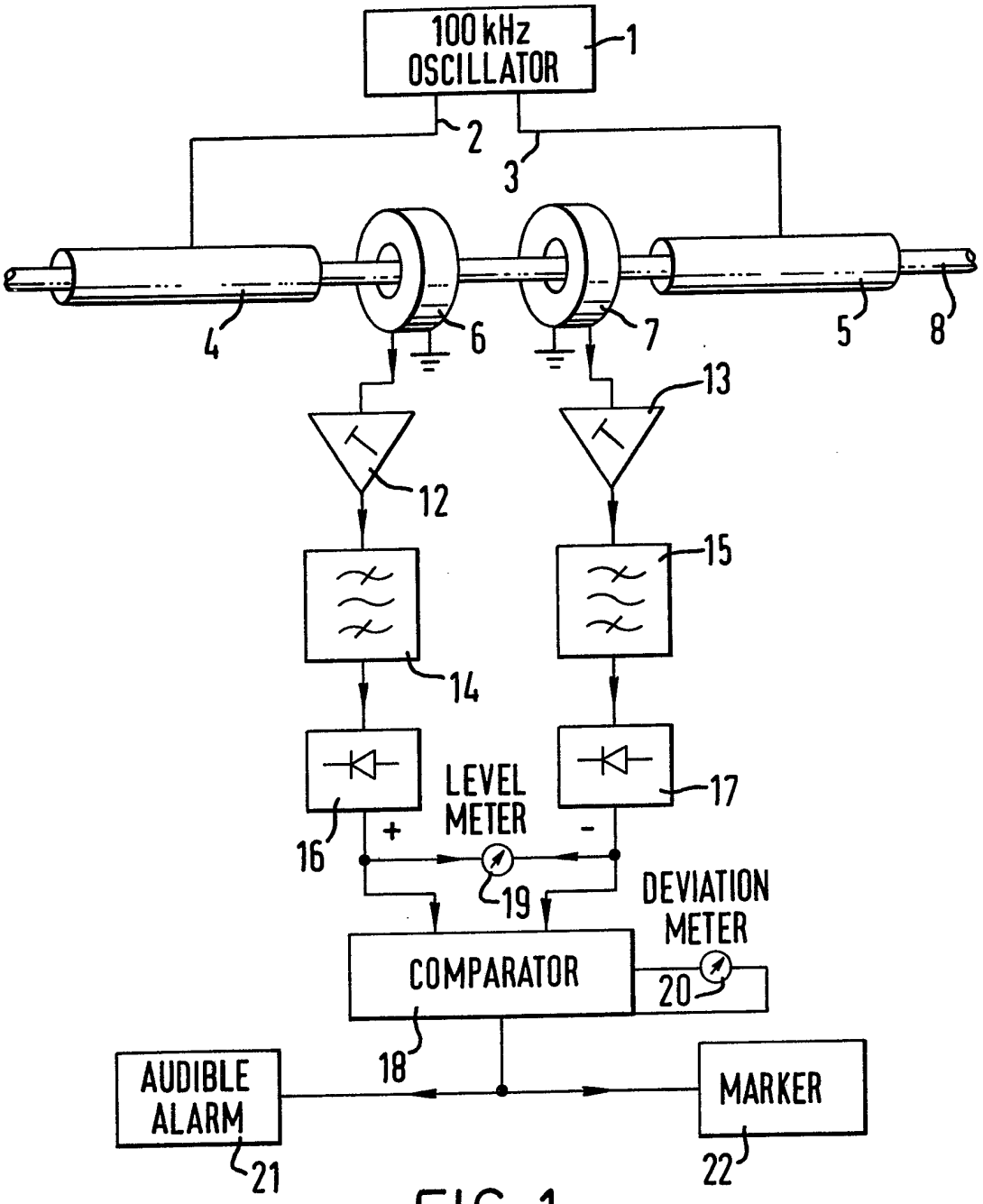
100 kHz
OSCILLATOR
1
2
3
4
5
6
7
8
12
13
14
15
16
17
LEVEL
METER
+
-
19
DEVIATION
METER
20
COMPARATOR
18
AUDIBLE
ALARM
21
MARKER
22

FIG. 1

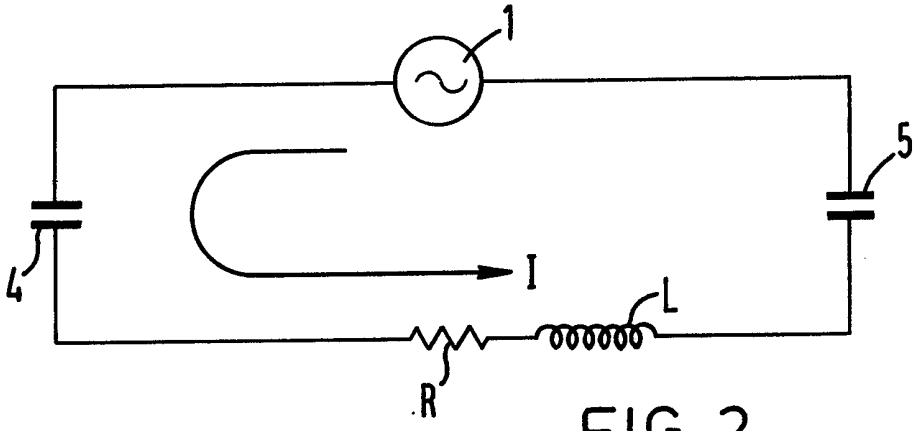

FIG. 2

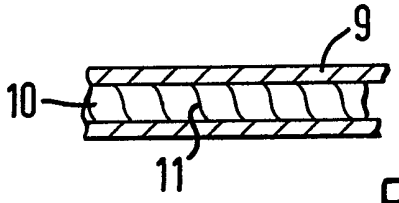

FIG. 3

SPECIFICATION

Detecting a Fault in an Insulated Electric Cable With a Spiral Electrical Conductor

The present invention relates to detecting a fault in an insulated electric cable with a spiral electrical conductor.

According to one aspect of the present invention, there is provided apparatus for detecting a fault in an insulated electric cable with a spiral electrical conductor, the apparatus comprising:

a) first means, for coupling an alternating current to such an electrical conductor in such a cable, which current flows along the conductor;

b) sensing means, for sensing magnetic flux due to current coupled to such a conductor; and

c) third means, coupled with the sensing means and responsive to a change in such magnetic flux due to a fault in such a cable.

According to another aspect of the present invention, there is provided a method of detecting a fault in an insulated electric cable with a spiral electrical conductor, the method comprising:

a) coupling an alternating current to the electrical conductor, which current flows along the conductor;

b) sensing magnetic flux due to the current coupled to the conductor; and

c) with means coupled with the sensing means, responding to a change in the magnetic flux due to a fault in the cable.

The alternating current could be coupled to the electrical conductor via capacitive coupling means, for example via first and second spaced-apart capacitive coupling devices relative to which the cable passes (such as first and second metal tubes through which the cable passes), each of the devices being coupled to a respective side of a balanced output of an oscillator.

Magnetic flux due to current coupled to the conductor could be sensed by sensing means comprising a pair of spaced-apart matched coils through which the cable passes, the means coupled with the sensing means comprising first detecting means, coupled with an output of the first coil, and second detecting means, coupled with an output of the second coil, and comparison means for comparing output signals from the first and second detecting means. If the alternating current is coupled to the conductor via first and second spaced-apart capacitive coupling devices, the coils are between these devices. Each of the detecting means could comprise amplifying means, filter means and signal level detector means, an output of each of the level detector means being coupled with a respective input of the comparison means. There could be a level meter coupled between the outputs of the signal level detector means. A deviation meter could be coupled with the comparison means, for monitoring the extent to which signals compared by the comparison means differ. Moreover, there could be audible alarm means coupled with an output of the comparison means and activated if the latter indicates that signals it compares differ by more than a certain amount and/or marking means coupled with an output of the comparison means for marking the cable if the comparison means indicates that signals it compares differ by more than a certain amount.

The present invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows apparatus for detecting faults in an insulated electric cable with a spiral electrical conductor, together with such cable passing through the apparatus,

Figure 2 is an equivalent circuit diagram of part of the apparatus with cable passing through it, and

Figure 3 is a longitudinal cross-section through the cable.

Where insulated electric heating cable is constructed by winding wire spirally on to an insulated core, the pitch of the winding is usually critical and continuity vital. Variations in pitch can cause hot spots within the cable and this type of fault can be caused anywhere in the manufacturing process, and when the cable is provided with its insulation, such variations and open circuits are difficult to detect. There will now be described one example of apparatus according to the invention which may be used to detect both variations in winding pitch and discontinuities in the wire beneath the insulation of insulated electric heating cable after it has been provided with its insulation.

Referring first to Figure 1, the apparatus includes an oscillator 1 which generates a signal of 100 kHz at a voltage of 200 volts peak to peak. The oscillator 1 has a balanced output with two sides 2 and 3, with no earth reference, the side 2 being connected to a metal tube 4 and the side 3 being connected to a metal tube 5. Between the tubes 4 and 5 is a pair of matched coils 6 and 7 of 2000 turns each, insulated electric heating cable 8 to be tested being passed through the tubes 4 and 5 and the coils 6 and 7 after it has beem provided with its insulation. A longitudinal cross-section through the cable is shown in Figure 3, in which reference 9 denotes the insulation, reference 10 an insulating core and reference 11 an electrical wire wound spirally on to the insulating core 10.

Each of the tubes 4 and 5 acts as a plate of a capacitor and the cable as an inductor and a resistor, an alternating current I being caused to flow through the wire 11 of the cable due tocapacitive coupling via the tubes 4 and 5.

Figure 2 is an equivalent circuit diagram of the oscillator 1, the tubes 4 and 5 and the cable 8, the resistor R and the inductor L denoting the resistance and inductance respectively presented by the cable 8. The construction of the cable 8 is such that the wire 11 acts as a primary winding of a transformer, each of the coils 6 and 7 acting as a secondary winding. Each of the coils 6 and 7 is wound on an electrostatic shield to prevent capacitive coupling and provides an output signal

to a respective one of variable gain amplifiers 12 and 13 as a result of sensing magnetic flux due to the current I flowing in the wire 11. The output signals from the amplifiers 12 and 13 are passed to band-pass filters 14 and 15 respectively to filter noise and the output signals from the filters 14 and 15 are passed to signal level detectors 16 and 17 respectively. Each of the detectors 16 and 17 produces a DC signal level which is directly proportional to the amplitude of the alternating current signal applied to it but is of opposite polarity to the DC signal level produced by the other detector as the cable passes through the apparatus. The DC signal levels from the detectors 16 and 17 are compared in a comparator 18 and, if the latter detects that the DC levels differ by more than a certain amount (indicating a discontinuity in the wire 11 or a variation in its pitch greater than a certain amount), then an audible alarm 21 is activated and a marker 22 is activated—to mark the cable 8 being pulled through the tubes 4 and 5 and the coils 6 and 7. A level meter 19 is coupled between the outputs of the detectors 16 and 17 to monitor their output levels and a deviation meter 20 is coupled with the comparator 18 to indicate the extent of the difference in level between the DC levels applied to the comparator 18.

Claims

1. Apparatus for detecting a fault in an insulated electric cable with a spiral electrical conductor, the apparatus comprising:

a) first means, for coupling an alternating current to such an electrical conductor in such a cable, which current shows along the conductor;

b) sensing means, for sensing magnetic flux due to current coupled to such a conductor; and

c) third means, coupled with the sensing means and responsive to a change in such magnetic flux due to a fault in such a cable.

2. Apparatus according to claim 1, wherein the said first means comprises means for capacitively coupling an alternating current to such an electrical conductor in such a cable.

3. Apparatus according to claim 2, wherein the said first means comprises first and second spaced-apart capacitive coupling devices relative to which such a cable can pass, and an oscillator having a balanced output to respective sides of which the capacitive coupling devices are coupled.

4. Apparatus according to claim 3, wherein the coupling devices comprise metal tubes through which such a cable can pass.

5. Apparatus according to any preceding claim, wherein the third sensing means comprises a pair of spaced-apart matched coils through which such a cable can pass, the third means comprising first detecting means, coupled with an output of the first coil, and second detecting means, coupled with an output of the second coil, and comparison means for comparing output signals from the first and second detecting means.

6. Apparatus according to claim 5 as dependent upon either of claims 3 and 4, wherein the coils are between the coupling devices.

7. Apparatus according to claim 5 or 6, wherein each of the said detecting means comprises amplifying means, filter means, and signal level detector means, an output of each of the signal level detector means being coupled with a respective input of the comparison means.

8. Apparatus according to claim 7, including a level meter coupled between the outputs of the signal level detecting means.

9. Apparatus according to any of claims 5 to 8, including a deviation meter coupled with the comparison means for monitoring the extent to which signals compared by the comparison means differ.

10. Apparatus according to any of claims 5 to 9, including audible alarm means coupled with an output of the comparison means and activated if the latter indicates that signals it compares differ by more than a certain amount.

11. Apparatus according to any of claims 5 to 10, including marking means coupled with an output of the comparison means for marking such an electric cable if the comparison means indicates that signals it compares differ by more than a certain amount.

12. Apparatus for detecting a fault in an insulated electric cable, substantially as herein described with reference to the accompanying drawings.

13. A method of detecting a fault in an insulated electric cable with a spiral electrical conductor, the method comprising:

a) coupling an alternating current to an electrical conductor in the cable, which current flows along the cable;

b) sensing magnetic flux due to current coupled to the conductor; and

c) with means coupled with the sensing means, responding to a change in the magnetic flux due to a fault in the cable.

14. A method according to claim 13, wherein the alternating current is coupled capacitively to the electrical conductor.

15. A method according to claim 14, wherein the alternating current is coupled to the electrical conductor via first and second spaced-apart capacitive coupling devices relative to which thecable passes, each of the coupling devices being coupled to a respective side of a balanced output of an oscillator.

16. A method according to claim 15, wherein the coupling devices comprise metal tubes through which the cable passes.

17. A method according to any of claims 13 to 16, wherein the magnetic flux is sensed by a pair of spaced-apart matched coils through which the cable passes, signals derived from outputs of the coils being compared.

18. A method according to claim 17 as dependent on either of claims 15 and 16, wherein the coils are between the coupling devices.

19. A method according to claim 17 or 18,

wherein an output signal of each of the coils is respectively amplified, filtered and applied to signal level detector means, signal levels at outputs of the signal level detector means being compared.

20. A method according to claim 19, wherein signal levels from the signal level detector means are monitored by a level meter coupled between outputs of the level detector means.

21. A method according to any of claims 17 to 20, wherein the difference between signals compared is monitored by a deviation meter.

22. A method according to any of claims 17 to 21, wherein if the comparison indicates that signals compared differ by more than a certain amount, an audible alarm is produced by audible alarm means.

23. A method according to any of claims 17 to 22, wherein if the comparison indicates that signals compared differ by more than a certain amount, the cable is marked by marking means.

24. A method of detecting a fault in insulated electric cable, substantially as herein described with reference to the accompanying drawings.

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