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Circuit interrupting device having printed circuit board coils

Abstract

A testing system may include a printed-circuit board coil embedded on a printed circuit board. The testing system may further include a test circuit electrically connected to the printed-circuit board coil, the test circuit configured to: receive a signal from the printed-circuit board coil, analyze the signal from the printed-circuit board coil, and determine a fault based on the signal from the printed circuit board coil.

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Background/Summary

RELATED APPLICATIONS (1) This application claims priority to Ser. No. 17/985,758, filed on Nov. 11, 2022, which claims priority to U.S. patent application Ser. No. 16/520,588, filed Jul. 24, 2019, which claims priority to U.S. Provisional Patent Application No. 62/703,106, filed on Jul. 25, 2018, the entire contents of both of which are incorporated herein by reference.

FIELD
(1) Embodiments relate to circuit interrupting devices, such as a ground fault circuit interrupter (GFCI) and/or an arc fault circuit interrupter (AFCI).
SUMMARY
(2) Circuit interrupters are safety devices intended to protect a user from electric shock. GFCIs sense an imbalance in current flowing between hot and neutral conductors, and cut off power to the load, while AFCI sense an arc fault, and cut off power to the load. GFCI and/or AFCI may be implemented into electrical receptacles. In such an implementation, space within the electrical receptacle may be an issue.
(3) Thus, one embodiment provides a circuit interrupter including a line conductor, a printed-circuit board, and a test circuit. The printed-circuit board coil is embedded on a printed circuit board. The printed circuit board includes a slot through the printed-circuit board coil, wherein the line conductor is received by the printed-circuit board coil. The test circuit is electrically connected to

the printed-circuit board coil. The test circuit is configured to determine a condition of the line conductor based on a signal of the printed-circuit board coil.
(4) Other aspects of the application will become apparent by consideration of the detailed description and accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a perspective cutaway view of a circuit interrupting device according to some embodiments.
(2) FIGS. **2**A and **2**B are perspective views of a core assembly of the circuit interrupting device of FIG. **1** according to some embodiments
(3) FIG. **3** is a perspective view of a coil of the circuit interrupting device of FIG. **1** according to some embodiments.
(4) FIG. **4** is a block diagram of a control system of the circuit interrupting device of FIG. **1** according to some embodiments.
(5) FIG. **5** is a block diagram of an arc fault detector of the control system of FIG. **4** according to some embodiments.
(6) FIG. **6** is a perspective view of a printed-circuit board of a circuit interrupting device according to some embodiments.
(7) FIG. **7** is a perspective view of a printed-circuit board of a circuit interrupting device according to some embodiments.
DETAILED DESCRIPTION
(8) Before any embodiments of the application are explained in detail, it is to be understood that the application is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The application is capable of other embodiments and of being practiced or of being carried out in various ways.
(9) FIG. **1** is a perspective cutaway view of a circuit interrupting device **100** according to some embodiments. The circuit interrupting device **100** includes a housing **105** having a front cover **110** and a rear cover **115**. The housing **105** may be formed of plastic, or a similar material.
(10) The front cover **110** may include a duplex outlet face **120** with a phase opening **125**, a neutral opening **130**, and a ground opening **135**. The face **120** may further include an opening **140** accommodating a RESET button **145**. Although not illustrated, in some embodiments, the face **120** may include additional openings to accommodate additional buttons (for example, a TEST button), as well as additional openings to accommodate various indicators (for example, light-emitting diodes (LEDs), buzzers, etc.). The rear cover **115** is secured to the front cover **110** and may include one or more terminal screws **150**. In some embodiments, the terminal screws **150** include a line terminal screw, a neutral terminal screw, and/or a ground terminal screw. Contained within the front and rear covers **110**, **115** is a manifold **155**. Manifold **155** provides support for a yoke/bridge assembly **165** configured to secure the device **100** to an electrical box.
(11) FIGS. **2**A and **2**B illustrate perspective views of a core assembly **200** according to some embodiments. The core assembly **200** is configured to support a printed circuit board **205** that supports most of the working components of the device **100**, including the control system **400** illustrated in FIG. **4**. The core assembly **200** further supports a line conductor **210** and a neutral conductor **215**. The line and neutral conductors **210**, **215** are respectively electrically connected to the line terminal and neutral terminal, and are configured to supply electrical power to the device **100**.
(12) The core assembly **200** may further support a first coil **220** and a second coil **225**. As

illustrated, the first and second coils **220**, **225** may respectively include first and second apertures **230**, **235**. In some embodiments, the first aperture **230** is configured to receive the line conductor **210**, while the second aperture **235** is configured to receive the neutral conductor **215**. In some embodiments, the first and second coils **220**, **225** may respectively be embedded into first and second printed circuit boards **240**, **245**. In other embodiments, the first and second coils **220**, **225** may be embedded into a single printed circuit board. In some embodiments, the first coil **220** and the second coil **225** are printed circuit board coils.

(13) The core assembly **200** may additionally support a third coil **250** having a third aperture **255**. In some embodiments, the third aperture **255** is configured to receive both the line conductor **210** and the neutral conductor **215**.

(14) FIG. **3** illustrates one embodiment of the first coil **220** with the printed circuit board removed for illustrative purposes. As illustrated, the first coil **220** may be a Rogowski coil having an input **305** and an output **310**. As illustrated, the coil **220** further includes an upper portion **315**, a lower portion **320**, an inner portion **325**, an outer portion **330**, a plurality of helical conductors **335**, and a plurality of nodes **340**, connecting the input **305** to the output **310**. As illustrated, the helical conductors **335**, along with the nodes **340**, form the coil **220**. For example, the plurality of conductors **335** form a portion of the coil **220** between the inner portion **325** and the outer portion **330**, while the plurality of nodes **340** form the coil **220** between the upper portion **315** and the lower portion **320**.

(15) In some embodiments, the second coil **225** is also Rogowski coil, similar to coil **220**. Although not illustrated, in some embodiments the third coil **250** may also be a Rogowski coil embedded on a printed circuit board (for example a third printed circuit board or a single printed circuit board including the first, second, and third coils **220**, **225**, **250**. In some embodiments, coils **220**, **225**, and/or **250** are printed-circuit board coils that do not have a Rogowski coil configuration.

(16) FIG. **4** is a block diagram of a control system, or testing circuit, **400** of the device **100** according to some embodiments. The control system **400** includes a controller, or microcontroller, **405** electrically connected to the first coil **220**, the second coil **225**, and the third coil **250**. The controller **405** is configured to detect one or more fault conditions, and place the device **100** into a tripped state when the one or more fault conditions are detected. In some embodiments, the controller **405** is a well-known integrated circuit device having an electronic processor and a memory, such as but not limited to a **4145** device.

(17) The controller **405** may include a ground fault detection unit **410**, a resonator **415**, an arc fault detection unit **420**, and a time-domain correlator and analyzer **425**. In some embodiments, the ground fault detection unit **410**, the resonator **415**, the arc fault detection unit **420**, and/or the time-domain correlator and analyzer **425** are implemented in whole or in part in software. In some embodiments, there is no separate module, but rather the ground fault detection unit **410**, the resonator **415**, the arc fault detection unit **420**, and/or the time-domain correlator and analyzer **425** are implemented using software stored in the memory of the controller **405** and executed by the processor of the controller **405**.

(18) The ground fault detection unit **410** is configured to analyze electric signals from the third coil **250**. The ground fault detection unit **410** is configured to detect a ground fault (for example, a real ground fault, a simulated ground fault, a self-test ground fault, and/or a real or simulated grounded neutral fault based on the electric signals from the third coil **250**. The resonator **415** is configured to analyze a frequency of the power supplied to the device **100**.

(19) The arc fault detection unit **420** is configured to analyze electric signal from the first coil **220** or from the first coil **220** and second coil **225**. The arc fault detection unit **420** is configured to detect an arc fault (for example, a real arc fault, a simulated arc fault, and/or a self-test arc fault) based on the electric signals from the first coil **220** or from the first coil **220** and second coil **225**. The time-domain correlator and analyzer **425** is configured to perform a time-domain transformation and/or analysis on the electric signals from the first coil **220** or from the first coil

220 and second coil **225**. The transformed electric signals are then analyzed by the arc fault detection unit **420** to detect an arc fault. In some embodiments a discrete Fourier transform (DFT) is performed on the electric signal and then analyzed to further determine an arc fault.

(20) FIG. **5** is a block diagram of the arc fault detection unit **420** according to some embodiments. In such an embodiment, the arc fault detection unit **420** includes a bandpass filter **505**, an integrator **510**, and a gain stage, or scaling module, **515**. The electric signals from the first coil **220** or from the first coil **220** and second coil **225** are filtered by the bandpass filter **505** and then integrated by integrator **510** in order to determine a voltage of the electric signal(s). In some embodiments, the voltage is proportional to a current flowing through the first coil **220** and/or the second coil **225**. In some embodiments, the bandpass filter **505** is a 3-dB pass-band filter between 1-Hz and 8-kHz, which attenuates unnecessary low and high frequency content that might otherwise saturate the integrator **510**. Once integrated, the gain stage **515** scales the signal to a full-scale input voltage of an analog-to-digital (A/D) converter, which will sample the signal for subsequent digital post-processing. For example, a 30-Arms line-current may be scaled to a full-scale voltage of approximately 3.0 Vdc by the A/D converter. In some embodiments, the A/D converter is embedded within the controller **405**.

(21) As illustrated in FIG. **5**, in some embodiments, the interrupter **100** may further include coils **520**, **525**. Coil **520** may be electrically connected to coil **220** in a series-type configuration, while coil **525** may be electrically connected to coil **225** in a series-type configuration. Coils **520**, **220** and coils **525**, **225**, when respectively electrically connected in a series-type configuration, may produce respective measured signals that are multiplied by a n number of coils connected in the series-type configuration. Such an embodiment may allow for a greater measured signal.

(22) FIG. **6** illustrates a printed-circuit board **600** according to some embodiments. Printed-circuit board **600** may be part of, or included in, circuit interrupting device **100**. The printed-circuit board **600** may include one or more printed-circuit board coils **605**, one or more electronic components **610**, and one or more electrical pins **615**. Printed-circuit board coils **605** may be substantially similar to coils **220**, **225**, and/or **250**. The one or more electrical components **610** may include one or more components discussed above with respect to FIGS. **4** and **5**. For example, the one or more electrical components **610** may be, or may include, a programmable microcontroller. The one or more electrical pins **615** may be configured to electrically and/or communicatively connect the printed-circuit board **600** to other components of the circuit interrupting device **100**.

(23) In the illustrated embodiment, printed-circuit board **600** further includes one or more slots, or apertures, **620**. The slots **620** may be configured to receive the line conductor **210** and/or neutral conductor **215**.

(24) FIG. **7** illustrates a printed-circuit board **700** according to other embodiments. Printed-circuit board **700** may be part of, or included in, circuit interrupting device **100**. The printed-circuit board **700** may include one or more coils **705** and one or more slots, or apertures, **710**. In the illustrated embodiment, the one or more coils **705** are wire-wound coils. The slots **710** may be configured to receive the line conductor **210** and/or neutral conductor **215**.

(25) In operation, the coils (for example, coils **220**, **225**, **250**, **605**, and/or **705**) may be used to sense and/or monitor a current. An arc condition may then be determined based on the current. In some embodiment, an arc condition may be determined by determining if a correlation condition, a volatility condition, and/or an impulse condition exists. Additionally, in some embodiments, an in-rush condition may be detected via the coils.

(26) Thus, the application provides, among other things, a circuit interrupting device having a printed circuit board coil. Various features and advantages of the application are set forth in the following claims. For example, one advantage of the application includes an increase in within an electrical receptacle due to the reduced footprint of using one or more printed circuit board coils.

Claims

1. A testing system comprising: a printed-circuit board coil embedded on a printed circuit board; and a test circuit electrically connected to the printed-circuit board coil, the test circuit configured to: receive a signal from the printed-circuit board coil, analyze the signal from the printed-circuit board coil, and determine at least one selected from a group consisting of a: a volatility condition, an impulse condition, and an in-rush condition based on the signal from the printed circuit board coil.
2. The testing system of claim 1, wherein the analyzing of the signal from the printed-circuit board includes a time-domain transformation.
3. The testing system of claim 1, wherein the analyzing of the signal from the printed-circuit board includes performing a Fourier transform on the signal.
4. The testing system of claim 1, wherein the analyzing of the signal from the printed-circuit board includes analyzing at least one selected from a group consisting of a voltage, a current, and a frequency of the signal.
5. The testing system of claim 1, wherein the printed circuit board includes a slot through the printed-circuit board coil.
6. The testing system of claim 5, wherein a conductor is received within the slot.
7. The testing system of claim 1, wherein the printed-circuit board coil is a Rogowski coil.
8. The testing system of claim 1, wherein the analyzing of the signal includes filtering the signal.
9. The testing system of claim 8, wherein the filtering of the signal includes using a bandpass filter.
10. The testing system of claim 9, wherein the bandpass filter is a 3-dB pass-band filter between 1-Hz and 8-kHz.
11. A method of testing a signal comprising: receiving, at a test circuit, the signal from a printed-circuit board coil embedded on a printed circuit board; analyzing, via the test circuit, the signal from the printed-circuit board coil; and determining, via the test circuit, at least one selected from a group consisting of a volatility condition, an impulse condition, and an in-rush condition based on the signal from the printed circuit board coil.
12. The method of claim 11, wherein the analyzing of the signal from the printed-circuit board includes a time-domain transformation.
13. The method of claim 11, wherein the analyzing of the signal from the printed-circuit board includes performing a Fourier transform on the signal.
14. The method of claim 11, wherein the analyzing of the signal from the printed-circuit board includes analyzing at least one selected from a group consisting of a voltage, a current, and a frequency of the signal.
15. The method of claim 11, wherein the printed circuit board includes a slot through the printed-circuit board coil.
16. The method of claim 15, wherein a conductor is received within the slot.
17. The method of claim 11, wherein the printed-circuit board coil is a Rogowski coil.
18. The method of claim 11, wherein the analyzing of the signal includes filtering the signal.
19. The method of claim 18, wherein the filtering of the signal includes using a bandpass filter.
20. The method of claim 19, wherein the bandpass filter is a 3-dB pass-band filter between 1-Hz and 8-kHz.