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(71) Applicant
**Atreus Enterprises Limited (Irish Republic),
Kinnear Court, 16/20 Cumberland Street South,
Dublin 2, Republic of Ireland**

(72) Inventor
Patrick Joseph Ward

(74) Agent and/or address for service
C. P. Healy, 134 Grayswood Avenue, Coventry CV5 8HQ

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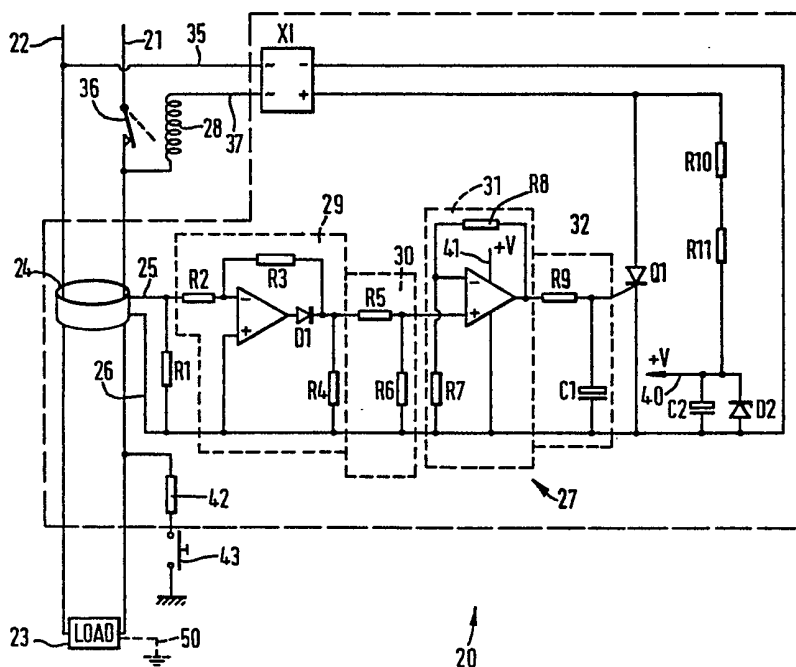
(56) Documents cited

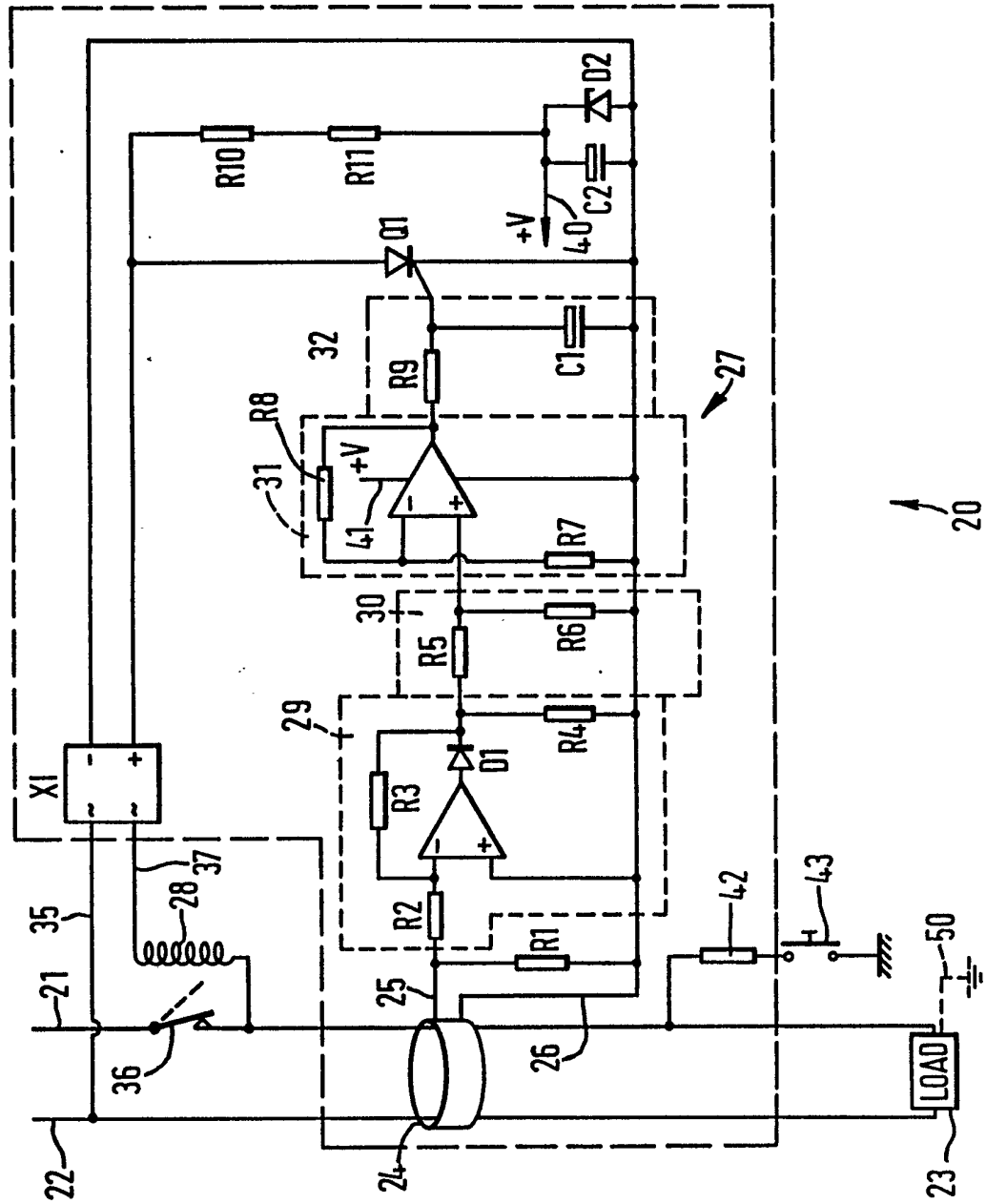
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(58) Field of search
**H2K
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(54) **Residual current device**

(57) A residual current device for use in combination with a line circuit breaker 36 to interrupt a mains supply in a two wire 21, 22 system. The device comprises switch means Q1 operable on receiving a predetermined signal level to activate the line circuit breaker 36. The signal is provided by circuit means 27 including a sense coil 24 for sensing a current imbalance in two conductors 21, 22, and for providing an output signal in response thereto, the output signal being fed to said switch means *via* an inverting amplifier 29, an attenuator 30, a high gain amplifier 31 and a filter 32.





SPECIFICATION

Improved residual current device

This invention relates to an improved residual current device (RCD).

Such devices have been previously referred to in the art as earth leakage circuit breakers (elcb's), and are widely used for detecting the presence of ground leakage signals from a load circuit and interrupting the circuit.

The known types of residual current devices (RCD's) are either electro-mechanical or electronic, however, both of the known types have disadvantages and it would be desirable to overcome these. For example, the electro-mechanical RCD's do not have the ability to sense DC components in ground fault situations. The known types of electronic RCD's have disadvantages which include, nuisance tripping due to noise on the mains, or due to surge currents under start up conditions. They may trip due to the presence of radio frequency (RF) noise on the mains. They may fail to trip when a ground fault current in excess of the rated tripping current is flowing, due to neutralisation of the sensing circuit by RF noise on the mains. They may have substantially different trip thresholds for ramp and step type ground faults. Other faults include, the inability to sense DC components in ground fault conditions, and the firing circuit of some known devices will only operate on positive polarity of the mains.

Furthermore, the known devices may fail to trip when powered up to a standing ground fault in excess of the trip threshold i.e. a low resistance path to earth exists prior to powering up the RCD, and the RCD fails to trip when switched on to such a condition. Also, the known devices have no surge protection for the electronic circuitry, resulting in destruction of components when the device is subjected to megger (R.T.M.) tests or high voltage spikes on the mains.

Thus, it is an object of the present invention to substantially mitigate the above referred disadvantages and to provide an improved residual current device.

According to the invention there is provided an improved residual current device for use in combination with a line circuit breaker to interrupt a mains supply in a two wire system, which comprises, switch means operable on receiving a predetermined signal level to activate the line circuit breaker, and circuit means for providing the signal, including a sense coil for sensing a current imbalance in two conductors and providing an output signal in response thereto, the output signal being fed to said switch means *via* full wave rectification and amplification means.

Preferably, the full wave rectification means comprises an operational amplifier configured as an inverting amplifier, with feedback to provide full wave rectification of the output signal from the sense coil.

The output signal from the full wave rectification means is preferably fed to a high gain amplifier

stage, *via* an attenuator. The attenuator is provided to reduce the signal level, so that a high gain amplifier stage is then required with the latter having a desired gain/frequency characteristic.

Preferably, the high gain amplifier stage has a gain of approximately 750 with an upper frequency response of about 1KHz.

The line circuit breaker is preferably a switch operated by a solenoid, the switch being connected in one of the conductors and the solenoid being connected between the dead side of the switch and an input terminal of an avalanche bridge rectifier.

The switch means preferably comprises a silicon controlled rectifier (SCR), connected across the output terminals of the avalanche bridge rectifier, such that, when the SCR is fired in response to the predetermined signal level, the output terminals of the bridge rectifier are short circuited across the two conductors, and the solenoid is energised to open the switch. The predetermined signal level is preferably approximately 510mVolts.

An embodiment of the invention will now be described, by way of example, with reference to the single accompanying drawing, of an improved residual current device according to the invention.

Referring now to the drawing, there is shown therein, an improved residual current device generally indicated at 20, for monitoring the current flowing in two conductors 21, 22 which are connected to a mains power supply (not shown), the former conductor 21 being a live conductor and the latter conductor 22 being a neutral conductor. Under balanced load conditions, all of the current flowing in the live conductor 21 will return *via* a load 23 through the neutral conductor 22. The load 23 may be a resistive, capacitive, or inductive load. The live and neutral conductors 21, 22 respectively, pass through the core of a sense coil 24. The sense coil 24 is a current transformer which is excited by a current carrying conductor passing through it. Under balanced load conditions there is no net excitation current available to excite the sense coil 24, since the current flowing in the live conductor 21, is the same as that flowing in the neutral conductor 22.

The output terminals 25, 26 of the sense coil 24 are connected as shown to the live and neutral conductors 21, 22 respectively, *via* circuit means, generally indicated at 27 and a solenoid coil 28. The circuit means 27 comprises a first-stage operational amplifier 29, an attenuator 30, a second-stage operational amplifier 31 and a filter 32. A resistor R1 is connected across the output terminals 25, 26 of the sense coil 24, and provides for an input voltage to the first-stage operational amplifier 29. The operational amplifier 29, is configured as an inverting amplifier and has an input resistor R2, an output diode D1, with feedback from the cathode of D1 *via* another resistor R3. This configuration provides full wave rectification of AC voltage at the input. The resistor R4 is an equalisation resistor. As the peaks of the output AC voltage from the amplifier 29 may be unequal, the resistor R4 acts as an equalisation resistor and thus, R4 is selected to make the peaks equal. The output from the amplifier 29 is fed to the attenuator 30, which comprises

resistors R5 and R6 which are selected to further reduce the output signal.

The output from the attenuator 30 is fed to the second-stage operational amplifier 31, which has a very high gain, typically 750. The amplifier 31 includes resistors R7 and R8. The gain of the amplifier 31 is set very high to take advantage of the gain/frequency characteristic of the amplifier, which is such that at high gain (750), the upper frequency response of the amplifier is pulled down to about 1KHz. This results in excellent immunity from radio frequency (RF) voltages which may be present on the mains power supply. The output from the amplifier 31 is fed to the filter 32 which comprises one resistor R9 and a capacitor C1. The output from the filter 32 is connected to switch means being the gate electrode of a silicon controlled rectifier Q1, which is connected across an avalanche bridge rectifier X1.

One input 35 to the avalanche bridge rectifier is connected to the neutral conductor 22. The live conductor 21 has a line circuit breaker comprising a switch 36 and the other input 37 to the bridge rectifier X1, is connected to the dead side of the switch *via* the solenoid coil 28. The positive output of the bridge rectifier X1 is fed *via* limiting resistors R10 and R11 to zener diode D2 and capacitor C2 which, as will be described, provide the power supply for the circuit means 27. In fact, the output terminal 40 from the capacitor C2 is connected to the terminal 41 for providing power to the circuit means 27.

The residual current device 20 further includes a test resistor 42, connected between the live conductor 21 and an earth point *via* a conventional closable test switch 43.

The quiescent state of the device is as follows with the switch 36 closed as shown. A small current of approximately 2mA is taken from the mains supply and full wave rectified by the avalanche bridge rectifier X1. The resistors R10 and R11 limit the current to the zener diode D2, which clamps the voltage on its cathode. The capacitor C2 smooths this rectified voltage signal and the smoothed signal provides the power source for the circuit means 27 *via* the terminals 40, 41. In the balanced condition equal currents are flowing in the conductors 21, 22 and thus, there is no net output voltage produced at resistor R1. Thus, the input to the amplifier 29 is zero and therefore the output from the amplifier 29 is also zero, resulting in zero drive voltage for the silicon control rectifier Q1. Thus, the device remains in the same condition.

Now, if the currents flowing in the conductors 21, 22 are different, due to an earth leakage as indicated at 50, possibly through a person or through a low resistance path, due to a badly insulated piece of equipment, a net current is caused to flow in the sense coil 24. This net current provides excitation of the sense coil 24, resulting in an output voltage being developed across the resistor R1. For an AC ground fault current, the resultant output voltage is a sinewave. The output voltage is full wave rectified by the amplifier 29, the negative half-cycles being inverted and the positive

half-cycles are added to the output at the cathode of diode D1. The output signal is significantly attenuated, but this is not important at this stage. The resistor R4 acts to make the output signal peaks equal at a suitable level. The level of the output signal is further reduced by the attenuator 30 and the output signal from the attenuator 30 is fed to the amplifier 31 where the signal is amplified with the high gain (750). The output signal from the amplifier is fed to the SCR (Q1) *via* the filter 32. The filter 32 provides a delay of approximately 3mSec for a fault condition of 27mAmps. This feature prevents short duration high level spikes, which may appear on the mains power supply from erroneously triggering the device.

However, if the fault current exceeds 27mAmps, the output signal from the amplifier 31 will rise above 510mVolts and such a voltage will fire the silicon controlled rectifier Q1.

As shown, the SCR Q1 is connected across the output terminals of the bridge rectifier X1, and thus, when Q1 turns on, a short circuit is effectively placed across the output terminals of the avalanche bridge rectifier X1. The solenoid coil 28 is now in effect connected directly across the mains power supply and thus a large current will flow through it. This sudden increase in current through the solenoid coil 28 will generate a powerful magnetic field, which will pull open the switch 36 to remove the power supply from the load. Thus, any danger of electrocution or fire is readily removed.

For a fault condition of 30mAmps, the action of the device will be completed within 30mSec. To test the correct functioning of the device the test switch 43 can be depressed. Furthermore, the use of the avalanche bridge rectifier X1 enables the device to withstand megger (R.T.M.) testing, the avalanche feature operating when the supply voltage exceeds 500 volts peak. With conventional residual current devices (RCD's) the RCD must be disconnected from circuitry before megger testing is carried out.

As well as sensing an AC ground fault, the residual current device 20 has the following special features. This device meets all of the requirements of BS4293 and IEC23E as presently drafted. Thus it can be used in British and European electrical systems. It will respond to both positive polarity and negative polarity ground faults. The device can fire on either half-cycle of the mains supply. The device will detect ground faults with partial rectification of the mains AC supply. The device has built in noise immunity, preventing the likelihood of nuisance tripping due to noise on the AC mains. The device will operate correctly with either capacitive or inductive loads.

The operating trip threshold is the same for either ramp or step type ground faults. (A ramp type ground fault is one whereby the fault current increases gradually from zero mAmps. A step type ground fault is one whereby the fault current increases suddenly from zero mAmps). Where a low resistance path to earth exists prior to switch-on, and where, under live conditions, this resistance value would allow a current to flow

whose value would exceed the stated trip threshold of the device, the device will, on power-up, immediately trip and remove power from the load.

- The device has built in protection against high voltage surges and spikes which appear on the mains. The device has built in immunity from RF noise signals up to an amplitude of 1.4Volts peak to peak, over a frequency range of 1KHz to 450MHz. The device will continue to operate correctly with the above RF signal levels present i.e. the device will continue to detect ground faults with a 50Hz component. At its rated trip threshold the device will normally trip within 30mSec. At 150mAmps the device will normally trip within 10mSec. Thus the degree of protection is increased with higher levels of ground fault. The trip threshold can be set to operate anywhere over the range 10mAmps to 500mAmps.

CLAIMS

1. An improved residual current device for use in combination with a line circuit breaker to interrupt a mains supply in a two wire system, which comprises, switch means operable on receiving a predetermined signal level to activate the line circuit breaker, and circuit means for providing the signal, including a sense coil for sensing a current imbalance in two conductors and providing an output signal in response thereto, the output signal being fed to said switch means *via* full wave rectification and amplification means.

2. A device as claimed in Claim 1, wherein the full

- 35 wave rectification means comprises an operational amplifier configured as an inverting amplifier, with feedback to provide full wave rectification of the output signal from the sense coil.

- 40 3. A device as claimed in Claim 1 or 2, wherein the output signal from the full wave rectification means is fed to a high gain amplifier stage *via* an attenuator.

- 45 4. A device as claimed in Claim 3, wherein the high gain amplifier stage has a gain of approximately 750 with an upper frequency response of about 1KHz.

- 50 5. A device as claimed in any preceding claim, wherein the line circuit breaker is a switch operated by a solenoid, the switch being connected in one of the conductors and the solenoid being connected between the dead side of the switch and an input terminal of an avalanche bridge rectifier.

6. A device as claimed in any preceding claim, wherein the switch means comprises a silicon controlled rectifier (SCR), connected across the output terminals of the avalanche bridge rectifier, such that, when the SCR is fired in response to the predetermined signal level, the output terminals of the bridge rectifier are short circuited across the two conductors, and the solenoid is energised to open the switch.

7. A device as claimed in Claim 6 wherein the predetermined signal level is approximately 510mVolts.

8. A device as claimed in Claim 1, substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.