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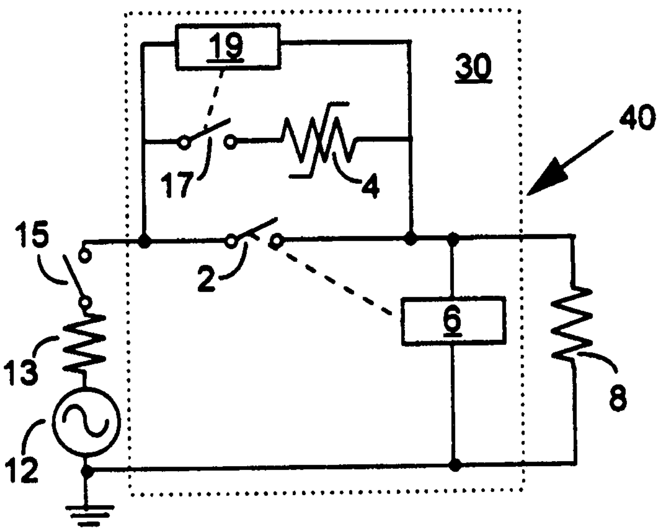

(57) Abstract

An electrical system which protects a circuit from overcurrents. The system includes a control element (6) connected in parallel with the load (8); a circuit interruption element (2); and a bypass element (4, 17, 19). A parallel combination of the circuit interruption and bypass elements is connected in series with the parallel combination of the electrical load and the control element. The circuit interruption element (2) has a closed state and an open state. The control element (6) has an on state, when the voltage across it is normal, and an off state, when the voltage across it falls to a value V_{FAULT}, or less; and is functionally linked to the circuit interruption element so that when the control element is in the on state, the circuit interruption element is in the closed state, and when the control element is in the off state, the circuit interruption element is in the open state. The bypass element comprises a first bypass path (17, 4) and a second bypass path (19) in parallel with the first bypass path; and has a start-up state and a stopped state. In the start-up state, if the circuit interruption element is in the open state and a current I_{NORMAL} is passing through the bypass element, substantially all the current through the bypass element passes through the first bypass path, and the voltage across the control element is greater than V_{FAULT}. In the stopped state, if the circuit interruption element is in the open state as a result of the voltage across the control element having fallen to a value V_{FAULT} or less, substantially all the current through the bypass element passes through the second bypass path, and the current through the bypass element is such that the voltage across the control element remains at a value of V_{FAULT} or less.

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OVERCURRENT PROTECTION CIRCUIT WITH IMPROVED PTC TRIP ENDURANCE

This invention relates to electrical circuit overcurrent protection.

PTC circuit protection devices are well known. The device is placed in series with a load, and under normal operating conditions is in a low temperature, low resistance state. However, if the current through the PTC device increases excessively, and/or the ambient temperature around the PTC device increases excessively, and/or the normal operating current is maintained for more than the normal operating time, then the PTC device will be "tripped," i.e. converted to a high temperature, high resistance state such that the current is reduced substantially. Generally, the PTC device will remain in the tripped state, even if the current and/or temperature return to their normal levels, until the PTC device has been disconnected from the power source and allowed to cool. Particularly useful PTC devices contain a PTC element which is composed of a PTC conductive polymer, i.e. a composition which comprises (1) an organic polymer, and (2) dispersed, or otherwise distributed, in the polymer, a particulate conductive filler, preferably carbon black. PTC conductive polymers and devices containing them are described, for example, in U.S. Patent Nos. 4,237,441, 4,238,812, 4,315,237, 4,317,027, 4,426,633, 4,545,926, 4,689,475, 4,724,417, 4,774,024, 4,780,598, 4,800,253, 4,845,838, 4,857,880, 4,859,836, 4,907,340, 4,924,074, 4,935,156, 4,967,176, 5,049,850, 5,089,801 and 5,378,407, the disclosures of which are incorporated herein by reference for all purposes.

A limitation on the known uses of PTC protection devices is that if the overcurrent is relatively small, e.g. up to a few times the normal circuit current, it can take a relatively long time to convert the PTC device into its tripped state. U.S. Patent No. 5,666,254 and corresponding PCT publication No. WO 97/10635 disclose an overcurrent protection system which will give a rapid response to overcurrents which cause a reduction in the voltage across the load, e.g. a partial or complete short across the load, and is particularly suitable for protecting circuits when such a fault results in relatively small overcurrents. In that system, a control element is placed in parallel with the load. When the voltage across the load drops, so also does the voltage across the control element. The control element is functionally linked to a circuit interruption element which is in series with the load, so that, when the voltage across the control element drops, the circuit interruption element is changed from a relatively conductive state to a relatively non-conductive state (including a completely open state). The system also includes a bypass element which is in parallel with the circuit interruption element. The bypass element is required so that, when the circuit is just switched on, current can pass through to the circuit and energize the control element, which then converts the circuit interruption element to the relatively conductive state. The bypass element must, however, be such that if a fault converts the circuit interruption element to the relatively non-conductive state, the resultant current through the bypass element changes the bypass element to a high impedance so that the voltage across the control element remains low enough to maintain the circuit interruption element in the relatively non-conductive state.

In a preferred embodiment of the invention disclosed in U.S. Patent No. 5,666,254 and corresponding PCT publication No. WO 97/10635, the circuit interruption element is a set of relay contacts which are normally open, and the control element is a relay coil which, when energized, closes the relay contacts, and which, when deenergized, allows the contacts to open; and, the bypass element is a PTC device, preferably a polymeric PTC device. During normal circuit operation, the relay coil is energized, thereby closing the contacts. In case of an undervoltage, the relay coil deenergizes, opening the contacts. Current is diverted to the PTC device which trips to its high resistance state. The combination of the PTC device and the mechanical contacts permits the use of contacts which are rated to interrupt the overcurrent, but at a voltage substantially less than the normal circuit voltage. The combination also permits the use of a PTC device which is rated to trip at a current level which is substantially less than the normal circuit current.

However, when the relay contacts are open, and the PTC device is in its high resistance state, the PTC device must withstand the source voltage until the relay is reset, e.g. by recycling power. In some circuit applications, this could affect the trip endurance of the PTC, i.e. the stability of the device over time when powered into a high resistance, high temperature state. Therefore, there is a need to provide a means to remove the source voltage from the PTC, while still keeping the circuit protection arrangement in a fault state, thereby continuing to protect the load.

We have now discovered a new overcurrent protection system which will give a rapid response to overcurrents which cause a reduction in the voltage across the load, e.g. a partial or complete short across the load, and which will preserve the trip endurance of a PTC device used in the protection system. The new system maintains the trip endurance of the PTC device by removing the source voltage from the PTC, while still keeping the circuit protection arrangement in a fault state, thereby continuing to protect the load. These results are achieved through the use of a by-pass element having two by-pass paths connected in parallel.

In the new system, a control element is placed in parallel with the load. When the voltage across the load drops, so also does the voltage across the control element. The control element is functionally linked to a circuit interruption element which is coupled in parallel with a bypass element, with the parallel combination coupled in series with the parallel combination of the control element and the load. When the voltage across the control element drops, the circuit interruption element is changed from a relatively conductive state to a relatively non-conductive state (including a completely open state).

The bypass element has two parallel paths. When the circuit interruption element changes to a relatively non-conductive state, current is diverted to the bypass element, with substantially all of the current flowing through a first bypass path. A PTC device coupled in the first bypass path is initially in a low impedance state. In response to the diversion of current through the first bypass path, the PTC device increases in resistance, thereby diverting current through a second bypass path. A bypass sensor, e.g. a relay coil or a voltage divider, in the second bypass path, senses the voltage level across the bypass element. When the voltage across the bypass element reaches a predetermined level, the bypass sensor causes a bypass switch, e.g. relay contacts or an FET, coupled in series with the PTC device, to switch from a closed or on state to an open or off state. The impedance of the bypass sensor is high enough so that as long as power continues to be applied, a very low current continues to flow through the bypass sensor, thereby keeping the bypass switch in the off or open state, but allowing very little current to flow through the load. This also keeps current through the PTC device very low (or zero) and applies the source voltage across the bypass sensor and bypass switch, thereby allowing the PTC device to return to its low impedance state. The bypass element, is arranged such that if a fault converts the circuit interruption element to the relatively non-conductive state, the resultant current through the bypass element changes the bypass element so that the voltage across the control element remains low enough to maintain the circuit interruption element in the relatively non-conductive state.

The bypass element serves the additional function that when the circuit is just switched on, current can pass through to the circuit and energize the control element, which then converts the circuit interruption element to the relatively conductive state.

In a preferred aspect, this invention provides an electrical system which can be connected between an electrical power supply and an electrical load to form an operating circuit, and which when so connected protects the circuit from overcurrents, which system comprises:

a. a control element which, in the operating circuit, is connected in parallel with the load; and

b. a circuit interruption element and a bypass element which, in the operating circuit, are connected in parallel, the parallel combination of the circuit interruption element and the bypass element being connected in series with the parallel combination of the electrical load and the control element;

wherein

i. the circuit interruption element has

(1) a closed state which permits the flow of a normal current, I_{NORMAL}, through the circuit interruption element, and

(2) an open state which permits the flow of at most a reduced current, substantially less than I_{NORMAL}, through the circuit interruption element;

ii. the control element

(1) has an on state, when the voltage across the control element is a normal voltage, V_{NORMAL}, and an off state, when the voltage across the control element falls to a value V_{FAULT}, or less, and

(2) is functionally linked to the circuit interruption element so that when the control element is in the on state, the circuit interruption element is in the closed state, and when the control element is in the off state, the circuit interruption element is in the open state;

iii. the bypass element

(1) comprises a first bypass path and a second bypass path which is in parallel with the first bypass path; and

(2) has a start-up state such that, if the circuit interruption element is in the open state and a current I_{NORMAL} is passed through the bypass element, substantially all the current through the bypass element passes through the first bypass path, and the voltage across the control element is greater than V_{FAULT}, and

(3) a stopped state such that if the circuit interruption element is in the open state as a result of the voltage across the control element having fallen to a value V_{FAULT} or less, substantially all the current through the bypass element passes through the second bypass path, and the current through the bypass element is such that the voltage across the control element remains at a value of V_{FAULT} or less.

In a preferred embodiment of the invention, the circuit interruption element is a first set of relay contacts which are normally open, and the control element is a first relay coil which, when energized, closes the first set of relay contacts, and which, when deenergized, allows the first set of relay contacts to open. The first bypass path is a series combination of a PTC device and a second set of relay contacts which are normally closed, and the second bypass path is a second relay coil which, when energized, opens the second set of relay contacts, and when deenergized, allows the second set of relay contacts to close. In case of an overcurrent resulting in a voltage drop across the first relay coil, the first relay coil deenergizes allowing the first set of relay contacts to open, thereby diverting current to the parallel combination of the first and second bypass paths. In the low impedance state, the impedance of the PTC device is substantially smaller than that of the second relay coil. Therefore, substantially all of the diverted current passes through the first bypass path, including the PTC device. In response to the increased current, the PTC device heats up and increases its impedance, thereby diverting current to the second bypass path, i.e. the second relay coil. The second relay coil energizes, thereby opening the second set of contacts, thereby stopping the flow of current through the PTC device which cools and returns to its low impedance state. As long as power is applied, and the cause of the overcurrent condition remains, a small amount of current continues to flow through the second relay coil, thereby keeping the second relay coil energized and the second set of contacts open. Substantially all of the applied source voltage appears across the second relay coil and the second set of relay contacts, and there is very little or no voltage across the PTC device.

In another preferred embodiment, both relay coils are replaced by voltage dividers and both sets of relay contacts are replaced by FETs. The outputs of the voltage dividers are coupled to the gates of the respective FETs. The operation of the protection system is essentially the same as described above, with the primary difference being in that in the OFF state, both FETs may allow a very small leakage current to flow.

Both of the preferred embodiments provide a rapid response to overcurrents which cause a reduction in the voltage across the load. Both embodiments maintain the trip endurance of the PTC device by removing the source voltage from the PTC, while still keeping the circuit protection arrangement in a fault state, thereby continuing to protect the load. The solid state arrangement has an advantage over the relay arrangement in that the voltage dividers can be selected to present a much higher impedance than that of the relay coils, thereby consuming much less power than that consumed by the relay coils. The solid state arrangement has the additional potential advantages of longer life, lower cost and smaller size.

The invention is illustrated in the accompanying drawings, in which like components are given the same reference numerals in each FIG. in which they appear, and in which:

FIG. **1** is a modified version of Fig. **1** of U.S. Patent No. 5,666,254 and WO 97/10635, the modification being that the by-pass element **106** contains two bypass paths **105, 107**. Five operational elements depicted in FIG. **1** are a source **102**, a control element **104**, the bypass element **106**, an interrupt element **108** and a load **112**. The source **102** provides the electrical power to the circuit, and the load **112** performs the intended purpose of the circuit. The control **104**, interrupt **108**, and bypass **106** elements work cooperatively to provide overcurrent protection.

FIG. **2** is the same as FIG. **2** in U.S. Patent No. 5,666,254 and WO 97/10635. It shows an electrical circuit **20**, comprising a power source **12**, a source impedance **13**, a switch **15**, a load **8**, and an overcurrent protection system **10**. The overcurrent protection system **10** comprises a normally open first set of relay contacts **2**, a PTC device **4** connected in parallel with the relay contacts, and a voltage-sensing first relay coil **6** connected in parallel across the load **8**. In normal operation, when the power source **12** is connected by closing the switch **15**, the first set of relay contacts **2** are initially open, but the first relay coil **6** becomes energized via current flowing through the PTC device **4**, thereby closing the first set of relay contacts **2**. With the first set of relay contacts **2** closed, the PTC device **4** does not carry the normal circuit current. If a fault develops in the load **8**, the current in the circuit **20** increases, and the voltage across the load **8** and the first relay coil **6** is reduced, thereby deenergizing the first relay coil **6**, and opening the first set of relay contacts **2**. The overcurrent then flows through the PTC device **4** which then trips to its high resistance state and reduces the current to a safe level.

In the circuit of FIG. **2** , the first relay coil **6** functions as the control element **104** (FIG. **1**), the first set of relay contacts **2** function as the interrupt element **108**, and the PTC device **4** functions as the bypass element **102** of FIG. **1** of U.S. Patent Application Serial No. 08/564,457.

The presence of the PTC device **4** in parallel with the first set of relay contacts **2** permits the use of a first set of relay contacts **2** which are rated to carry the normal circuit current, and to interrupt the maximum overcurrent at a voltage which is less than the normal applied voltage. With the PTC device **4** having a low resistance state resistance of $R_{PTC\ LOW}$, and the circuit **20** having a maximum overcurrent with the load **8** shorted of $I_{MAX\ OVERCURRENT}$, then the first set of relay contacts **2** are rated to interrupt $I_{MAX\ OVERCURRENT}$ at a voltage less than $R_{PTC\ LOW} \times I_{MAX\ OVERCURRENT}$.

FIG. **3** shows an embodiment of a circuit protection arrangement of the present invention. FIG. **3** shows an electrical circuit **40** which is similar to the electrical circuit **20** shown in FIG. **2**. The protection system **30** in FIG. **3** differs from the protection system **10** in FIG. **2** in that the bypass element **106** (FIG. **1**) comprises two paths instead of a single path. A first bypass path **105** (FIG. **1**) comprises a PTC device **4** coupled in series with a second set of relay contacts **17**, and a second bypass path **107** (FIG **1**.) comprises a voltage-sensing second relay coil **19** coupled with the second set of relay contacts **17**.

In normal operation, when the power source **12** is connected by closing the switch **15**, the first set of relay contacts **2** are initially open and the second set of relay contacts **17** are initially closed. The first relay coil **6** becomes energized via current flowing through the second set of relay contacts **17** and the PTC device **4** (i.e., the first bypass path **105** (FIG. **1**)), thereby closing the first set of relay contacts **2**. With the first set of relay contacts **2** closed, substantially all the circuit current flows through the first set of relay contacts **2**. If a fault develops at the load **8**, the current in the circuit **40** increases, and the voltage across the load **8** and the first relay coil **6** is reduced, thereby deenergizing the first relay coil **6**, and opening the first set of relay contacts **2**. The overcurrent then flows through the second set of relay contacts **17** and PTC device **4.** The PTC device **4** trips to its high resistance state thereby diverting the current to the second relay coil **19** in the second bypass path **107** (FIG. **1**). The second relay coil **19** energizes and opens the second set of relay contacts **17** thereby opening the first bypass path **105** (FIG. **1**) and removing current from the PTC device **4**. The impedance of the second relay coil **19** is sufficiently high to keep the current in the circuit **40** sufficiently low to protect the load **8** and still keep the first relay coil **6** deenergized.

In the overcurrent protection arrangements **10, 30** shown in FIGs. **2** and **3**, the first relay coil **6** is energized continuously during normal operation, and therefore continuously draws power from the power source **12**. A solid state alternative to the circuit of FIG **2** is shown in the circuit **60** of FIG. **4**. This is the circuit shown in FIG **5** of U.S. Patent No. 5,666,254 and WO 97/10635. Instead of the relay coil **6** and relay contacts **2** shown in Figure **2**, the solid state system **50** comprises a solid state switch, such as a first field effect transistor (FET) **14**, connected in the line of the circuit **60**, with the gate of the first FET **14** connected to a first voltage divider **22**. The first voltage divider **22** comprises series connected resistors **16, 18** connected in parallel with the load **8** and coupled with the gate of the first FET **14**. The solid state arrangement **50** functions in essentially the same manner as does the overcurrent protection arrangement **20** of FIG. **2**. At turn on, the first FET **14** is initially off until a voltage appears across the load **8** and first voltage divider **22** by way of current flowing through the PTC device **4**. The voltage appearing at the gate of the first FET **14** turns the first FET **14** on, thereby allowing current to flow in the circuit **60**. If there is a short or other fault at the load **8**, the resulting undervoltage across the voltage divider **22** causes the first FET **14** to turn off. The current is then diverted to the PTC device **4** which trips to its high resistance state. The combination of the first FET **14** and PTC device **4** reduces the switching energy of the first FET **14** and can allow the use of a smaller FET.

FIG. **5** shows a second embodiment of a circuit protection arrangement of the present invention. FIG. **5** shows an electrical circuit **80** which comprises first and second bypass paths **105, 107** (FIG. **1**) similar to the protection system **30** in the circuit **40** shown in FIG. **3**, but employs solid state devices, e.g. FETs, similar to the protection system **50** in the circuit **60** shown in FIG. **2**. In the protection system **70** in FIG. **5,** a first bypass path **105** (FIG. **1**) comprises a PTC device **4** coupled in series with a second FET **24**, and a second bypass path **107** (FIG **1**.) comprises a second voltage divider **32** comprising series coupled resistors **26, 28** connected in parallel with the series combination of the second FET **24** and PTC device **4**. The second voltage divider **32** is coupled with the gate of the second FET **24**. The second FET **24** may be a p-channel junction FET (JFET) or other such device which is in a normally on state.

In normal operation, when the power source **12** is connected by closing the switch **15**, the first FET **14** is initially off and the second FET **24** is initially on. The first voltage divider **22** becomes energized via current flowing through the second FET **24** and the PTC device **4** (i.e., the first bypass path **105** (FIG. **1**)). The voltage at the gate of the first FET **14** goes sufficiently positive to turn the first FET **14** on. With the first FET **14** on, substantially all the circuit current flows through the first FET **14**. If a fault develops in the load **8**, the current in the circuit **80** increases, and the voltage across the load **8** and the first voltage divider **22** is reduced, thereby turning off the first FET **14**. The overcurrent then flows through the second FET **24** and PTC device **4.** The PTC device **4** trips to its high resistance state thereby diverting the current to the second voltage divider **32** in the second bypass path **107** (FIG. **1**). The increased voltage across the second voltage divider **32** raises the voltage at the gate of the second FET **24**, and turns off the second FET **24**. The current in the first bypass path **105** (FIG. **1**), including the PTC device **4**, is further reduced to the off state leakage current of the second FET **14**. The impedance of the second voltage divider **32** is sufficiently high to keep the current in the circuit **70** sufficiently low to protect the load **8** and thereby keep the first FET **14** turned off.

In the solid state protection system **70** shown in FIG. **5**, other arrangements may be used in place of the first and second voltage dividers **22**, **32**. For example, arrangements comprising zener diodes or other voltage regulating or clamping devices may be used.

The solid state overcurrent protection system **70** has an advantage over the relay overcurrent protection system **30** in that the values of the resistors **16**, **18** comprising the first voltage divider **22** can be selected to present a much higher impedance than that of the first relay coil **6**, thereby consuming much less power during normal operation than that consumed by the arrangement which includes the first relay coil **6**. The solid state arrangement **70** has the additional potential advantages of longer life, lower cost and smaller size. Other solid state switching devices such as bipolar transistors, triacs, and silicon controlled rectifiers may be used in place of the FETs. Hybrid combinations, e.g. a solid state arrangement used for the control **104** and interrupt **108** elements, with a relay arrangement used in the bypass element **106**, or the converse, e.g. a relay arrangement used for the control **104** and interrupt **108** elements, with a solid state arrangement used in the bypass element **106**, may also be used.

The foregoing detailed description of the invention includes passages which are chiefly or exclusively concerned with particular parts or aspects of the invention. It is to be understood that this is for clarity and convenience, that a particular feature may be relevant in more than just the passage in which it is disclosed, and that the disclosure herein includes all the appropriate combinations of information found in the different passages. Similarly, although the various figures and descriptions herein relate to specific embodiments of the invention, it is to be understood that where a specific feature is disclosed in the context of a particular figure, such feature can also be used, to the extent appropriate, in the context of another figure, in combination with another feature, or in the invention in general.

CLAIMS

1. An electrical system which can be connected between an electrical power supply and an electrical load to form an operating circuit, and which when so connected protects the circuit from overcurrents, which system comprises:

   a. a control element which, in the operating circuit, is connected in parallel with the load; and

   b. a circuit interruption element and a bypass element which, in the operating circuit, are connected in parallel, the parallel combination of the circuit interruption element and the bypass element being connected in series with the parallel combination of the electrical load and the control element;

   wherein

   i. the circuit interruption element has

      (1) a closed state which permits the flow of a normal current, I_{NORMAL}, through the circuit interruption element, and

      (2) an open state which permits the flow of at most a reduced current, substantially less than I_{NORMAL}, through the circuit interruption element;

   ii. the control element

      (1) has an on state, when the voltage across the control element is a normal voltage, V_{NORMAL}, and an off state, when the voltage across the control element falls to a value V_{FAULT}, or less, and

      (2) is functionally linked to the circuit interruption element so that when the control element is in the on state, the circuit interruption element is in the closed state, and when the control element is in the off state, the circuit interruption element is in the open state; and

   iii. the bypass element

(1) comprises a first bypass path and a second bypass path which is in parallel with the first bypass path; and

(2) has a start-up state such that, if the circuit interruption element is in the open state and a current I_{NORMAL} is passed through the bypass element, substantially all the current through the bypass element passes through the first bypass path, and the voltage across the control element is greater than V_{FAULT}, and

(3) a stopped state such that if the circuit interruption element is in the open state as a result of the voltage across the control element having fallen to a value V_{FAULT} or less, substantially all the current through the bypass element passes through the second bypass path, and the current through the bypass element is such that the voltage across the control element remains at a value of V_{FAULT} or less.

2. A system according to claim 1, wherein:

a. the control element comprises a first relay coil, which

(1) is energized when the voltage across the first relay coil is V_{NORMAL}, and

(2) is deenergized, when the voltage across the first relay coil falls to a value V_{FAULT} or less; and

b. the circuit interruption element comprises a first set of relay contacts which are coupled with the first relay coil, and which

(1) are closed when the first relay coil is energized, and

(2) are open when the first relay coil is deenergized.

3. A system according to claim 1, wherein:

a. the first bypass path comprises a series combination of a PTC device and a second set of relay contacts; and

b. the second bypass path comprises a second relay coil which is coupled with the second set of relay contacts;

wherein

i. when the bypass element is in the start-up state, the second relay coil is deenergized and the second set of relay contacts are closed, and

ii. when the bypass element is in the stopped state, the second relay coil is energized and the second set of relay contacts are open.

4. A system according to claim 3 wherein the PTC device is a polymeric PTC device.

5. A system according to claim 1, wherein:

a. the circuit interruption element comprises a first field effect transistor (FET), comprising a gate, a source, and a drain, which

(1) will allow the normal circuit current, I_{NORMAL}, to pass when the gate voltage of the first FET is a normal gate voltage, and

(2) will switch to permit the flow of at most a reduced current, substantially less than I_{NORMAL}, when the gate voltage of the first FET falls below the normal gate voltage by a predetermined gate voltage amount; and

b. the control element comprises a voltage divider which determines the gate voltage of the FET.

6. A system according to claim 1, wherein:

a. the first bypass path comprises a series combination of a PTC device and a second FET; and

b. the second bypass path comprises a second voltage divider which determines the gate voltage of the second FET;

wherein

i. when the bypass element is in the start-up state, the voltage across the second voltage divider is less than a predetermined bypass voltage amount, and the second FET is in an ON state; and

ii. when the bypass element is in the stopped state, the voltage across the second voltage divider is above the predetermined bypass voltage amount, and the second FET is in an OFF state, in which it will pass at most a reduced current.

7. An electrical circuit, comprising an electrical power supply, an electrical load, and an electrical protection system as claimed in any one of claims 1 to 6.

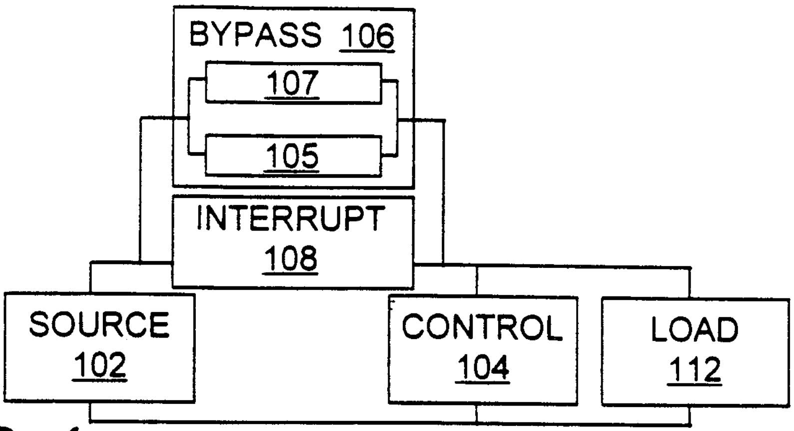

FIG. 1

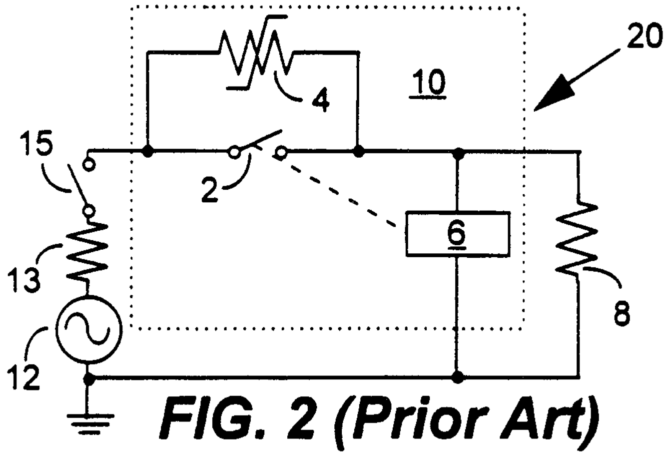

FIG. 2 (Prior Art)

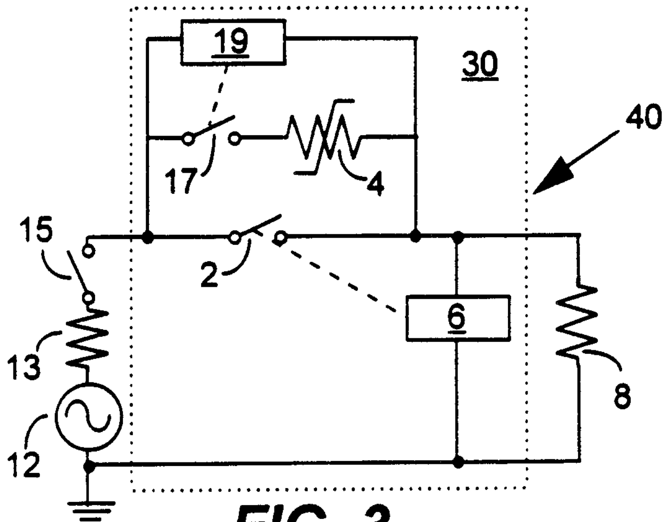

FIG. 3

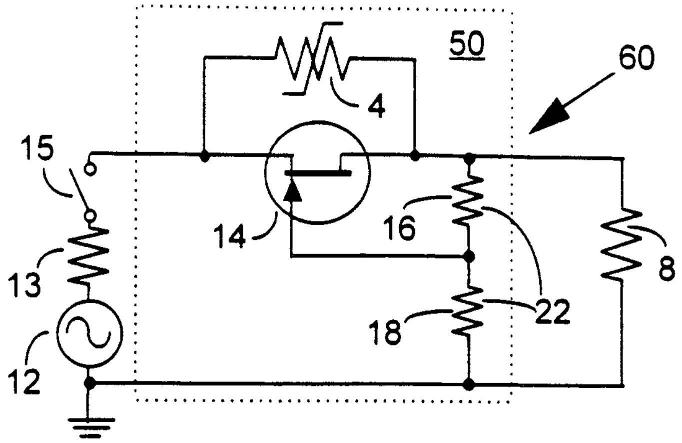

FIG. 4 (Prior Art)

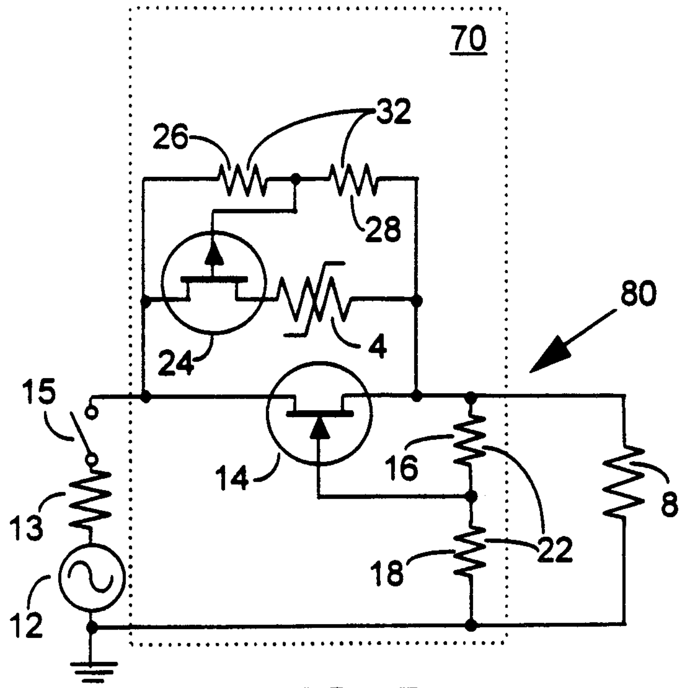

FIG. 5

INTERNATIONAL SEARCH REPORT

Interna[illegible]l Application No
PCT/US 98/16359

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H02H9/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H02H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 10637 A (RAYCHEM CORP) 20 March 1997 see page 4, line 23 - page 5, line 19; figure 2A ---	1
A	WO 97 10635 A (RAYCHEM CORP) 20 March 1997 cited in the application see abstract; figures 2-4 -----	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 October 1998	09/11/1998

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 98/16359

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9710637 A	20-03-1997	US 5689395 A	18-11-1997
		EP 0850505 A	01-07-1998
WO 9710635 A	20-03-1997	US 5666254 A	09-09-1997
		EP 0850503 A	01-07-1998