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LOAD PROTECTIVE DEVICE INCLUDING POSITIVE TEMPERATURE COEFFICIENT RESISTANCE

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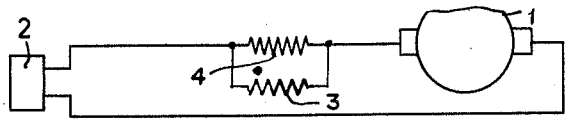


FIG.1

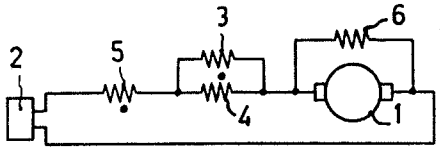


FIG.4

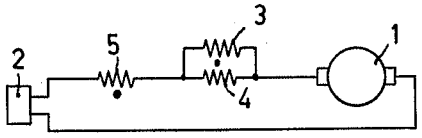


FIG.3

FIG. 2

INVENTOR.

EKKEHARD ANDRICH

BY

Frank R. Trifari

AGENT

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Ekkehard Andrich, Aachen, Germany, assignor to North American Philips Company, Inc., New York, N.Y., a corporation of Delaware

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13 Claims. (Cl. 318—442)

This invention relates to protective devices, and more particularly to a device by means of which a load may be automatically protected against overload conditions. By means of the present invention a load device such as the miniature motor in a shaving apparatus may be safely and reliably connected to two or more different supply voltages. A common arrangement used in the past includes a current limiting resistor which is usually arranged in a series circuit between the supply source and the load. In this arrangement the resistor can be short circuited by means of a mechanical switch when the device is connected to the lower supply voltage. The resistor and the switch are usually provided in the plug of the apparatus.

These devices suffer from the limitation that if the user of the apparatus, when connecting it to the higher supply voltage, forgets to open the shortcircuit of the current limiting resistor, the resulting current surge may overload the apparatus as a result of which it could become defective.

According to the present invention, the function of the switch is automatically performed by a current dependent resistor. The invention is characterized by the employment of the parallel combination of a fixed ohmic resistor whose resistance is substantially independent of temperature and a resistor having a high positive temperature coefficient (P.T.C.) of resistance. The expressions "fixed resistor" and "resistor having a high positive temperature coefficient" hold at least in the voltage range of the said supply voltages. This parallel combination is arranged in a series circuit between the source of supply voltage and the load. In particular, the current dependent resistor has so high a positive temperature coefficient of resistance that, when connected to the highest supply voltage available, it operates in the negative resistance region of its current-voltage characteristic curve. In fact, it is preferable that when the current dependent resistor is connected to the higher supply voltage, it operates at a considerably lower current than when it is connected to the lower supply voltage. The wide variation in resistance of the current-dependent resistor when connected to the higher or lower supply voltage in effect acts as an automatic electronic switch.

It is also known to connect an iron resistor having a rather large positive temperature coefficient in series with the load, thereby limiting the load current to a predetermined safe value. Such a resistor consequently operates as a current limiter and not as an electronic switch. Undesirable currents in this resistor and temperature variations will influence the current through the load to a considerable extent, which in turn adversely affects the reliability of the device. In the device in accordance with the invention, a considerable portion of the load current flows through the fixed resistor connected in parallel with the P.T.C. resistor. Therefore, the reliability of the device has been considerably increased. A further difference with respect to the iron resistors previously used consists in that the P.T.C. resistors used in the practice of this invention exhibit a high positive temperature coefficient only above a given temperature (for example 100° C.) and from a given power, respectively.

Below this temperature, that is to say as low as room temperature, this resistor may be considered to be an ohmic resistor which is substantially independent of temperature. However, iron resistors usually exhibit a positive temperature coefficient even at room temperatures. A method of fabricating a P.T.C. resistor particularly adapted for use with this invention is described and shown in the British specification 714,965.

It is therefore an object of this invention to provide an improved protective arrangement which permits a motor or other device to be safely and reliably connected to two or more different sources of supply voltage.

It is also an object of this invention to provide an overload protection arrangement which is of extremely simple construction and is reliable in operation.

In order that the invention may be readily carried into effect, it will now be described with reference to the accompanying drawing in which:

FIG. 1 shows a device in accordance with the invention;

FIG. 2 illustrates several waveforms helpful in understanding the invention including the current-voltage characteristic of a resistor having a positive temperature coefficient and the characteristic of the parallel combination of such a resistor and a fixed resistor which may be used in the device shown in FIG. 1.

FIG. 3 shows another embodiment of the invention.

FIG. 4 illustrates still another embodiment of the invention.

The device shown in FIG. 1 comprises a load **1**, for example, the miniature motor of an electric shaving apparatus, which may arbitrarily be connected to a higher alternating supply voltage, for example, of 220 volts, and to a lower alternating supply voltage, for example, 110 volts, respectively. In the interests of simplicity, the motor field windings have not been illustrated. To this end, according to the invention, the parallel combination of a fixed resistor **3** and a resistor **4** having a high positive temperature coefficient is provided in series between the load **1** and the supply voltage **2**. The resistor **4** has a current-voltage characteristic I–V as indicated in FIG. 2 by curve **4**. The current-voltage characteristic of the parallel combination of resistors **3** and **4** as indicated in FIG. 2 by the curve labelled **3+4**.

The circuit arrangement of FIG. 1 is proportioned so that at the lower supply voltage the parallel combination of resistors **3** and **4** is operated at the operating point A, whereas at the higher supply voltage it is operated at the operating point B, FIG. 2. The straight lines **1** and **1'** in FIG. 2 indicate the characteristic of the load **1** when connected to supply voltages of 110 volts and 220 volts, respectively.

In a particular embodiment of the invention, the load **1** has a resistance of, for example, 2,000 ohms. The value of the resistor **3** is, for example, 3,300 ohms. At the lower supply voltage of 110 volts, the resistor **4** has a resistance value of 200 ohms. When the device is connected to the higher supply voltage (220 v.) the resistance of resistor **4** has increased to a value of about 20,000 ohms and a load current flows in the circuit which corresponds to the operating point B. As can be seen from the operating point B' of the resistor **4** alone, this current has only increased to a slightly higher value than that of the resistor **3**, and the small residual current actually flowing through resistor **4** has only a slight influence on the total current through the load **1**.

The circuit arrangement described has the additional advantage that in the event the rotor of the motor **1** is braked too strongly, resulting in a sharp reduction in the counter E.M.F. produced by the motor, the current flowing through the motor is prevented from increasing

to a dangerously high value. In other words, the variation of the resistance value of the P.T.C. resistor 4 also acts as an automatic electric overload protection in the event of a sudden braking of the motor.

In order to obtain further overload protection for the device against the possible connection to an even higher supply voltage of, for example, 265 volts, another P.T.C. resistor 5, as shown in FIG. 3, may be added in series with the elements previously described. The latter resistor may also be provided instead of the resistor 4, if its resistance value and its maximum power dissipation are such that it fulfils the condition for operating point B of FIG. 2. In other words, replacing the series combination of resistors 4 and 5 by a single resistor 5 requires that resistor 5 must still remain ohmic at this operating point, and that it only reaches its P.T.C. range at a higher power level.

It is of course evident that the arrangements shown in FIGS. 1 and 3 are not limited to use with the motor load described, but may be used in connection with any arbitrary load requiring a similar automatic type of protection. Whereas in shaving apparatus the protective device is usually provided in the plug, a device in accordance with the invention may readily be arranged in the housing of the load itself and thermally isolated therefrom. Consequently, it is possible to use a conventional plug which results in the total arrangement becoming less expensive.

The following is a description of an improvement of the device described.

It has appeared that the load resistance, more particularly the internal resistance of the motor, may show considerable resistance variations which endanger the reliability of the device. Consequently, if the device is proportioned so that for one value of the load resistance it renders a reliable switching of the operating point possible when switching from one supply voltage to the other, it may happen that when connecting a load with a comparatively low internal resistance to the lower supply voltage, the maximum in the I–V characteristic of the P.T.C. resistor is exceeded and a wrong operating point is obtained. If, in order to prevent this danger, the P.T.C. resistor is proportioned so, that the maximum in its I–V characteristic lies comparatively high, again the danger exists that when connecting a load with a comparatively high internal resistance to the higher supply voltage, this maximum is not exceeded and too large a voltage is set up at the load.

According to a further feature of the invention, these difficulties may be avoided by connecting parallel to the load, a voltage-dependent resistor having a strongly increasing current conductivity in the voltage range between the values of the two supply voltages. For this purpose, parallel to the load 1 a voltage-dependent resistor 6 (V.D.R.), viz. FIG. 4, is connected, the conductivity of which strongly increases in the range between the values of the lower and the higher supply voltage. In addition, the P.T.C. resistor 4 is proportioned so that the maximum in the I–V characteristic lies considerably higher than the point of intersection A in FIG. 2. Its characteristic is represented by the curve 4*a* and the total characteristic of resistors 3 and 4 by the curve 3+4*a* in FIG. 2. A load having a considerably smaller internal resistance than corresponds to the straight line 1 in FIG. 2 will never be capable of exceeding the maximum in the curve 3+4*a* when connecting the device to the lower supply voltage and consequently it will result in a correct operating point.

However, if the load resistance is larger than corresponds to the straight line 1, without the resistor 6 the danger exists that when connecting the device to the higher supply voltage the corresponding straight line 1' intersects the curve 3+4*a* in the proximity of the current maximum, so that no switching to the operating point B would occur. In that case the voltage at the resistors 3–4 would be small and that at the load would consequently be inadmissibly high.

This latter voltage is so large that when connecting the device, the resistor 6 is immediately operated at an operating point where its current permeability has increased strongly. Its corresponding resistance then may be, for example, only 1000 ohms and the I–V characteristic of the parallel combination 1, 6 will then correspond, for example, the curve 1+6 in FIG. 2. In that case the current flowing in the device rises above the maximum in the I–V characteristics 3+4*a* and this current will rapidly heat the resistor 4 until an operating point is reached which corresponds approximately to the point B. As a result of this, however, the voltage drop at the resistors 3–4 increases so strongly that the voltage at the load 1 and at the resistor 6 respectively is again reduced to the required lower value. However, at this voltage the resistor 6 again has a high value, for example, a few times 10,000 ohms, so that it causes only a slight additional current load on the supply source.

In a practical example, with the above proportioning of the circuit elements 1, 3 and 4, the resistor 6 was chosen such that at 110 v. it had a value of 27,500 ohms. However, at 220 v. it had a value of 1,000 ohms.

Although the invention has been described with reference to three specific embodiments, its principles have been set forth in sufficient detail to enable those skilled in the art to design and construct other useful apparatus embodying these principles.

What is claimed is:

1. Protective apparatus for an electrical load device adapted for connection to a source of electrical energy having first and second voltage levels, said second voltage level being higher than said first voltage level, comprising a pair of parallel connected resistance elements serially connected with said energy source and said load device, one of said resistance elements having a positive temperature coefficient of resistance above a predetermined voltage level, said positive temperature coefficient resistance element undergoing a variation in resistance between said first and second voltage levels which produces a lower value of current flow therein at said second voltage level than occurs therein at said first voltage level and the other resistance element having a small temperature coefficient of resistance relative to the temperature coefficient of said one resistance element.

2. Protective apparatus for an electrical load device adapted for connection to a source of electrical energy having first and second voltage levels, said second voltage level being higher than said first voltage level, comprising a pair of parallel connected resistance elements serially connected between said energy source and said load device, one of said resistance elements having a high positive temperature coefficient of resistance above a predetermined voltage level and a low temperature coefficient below said predetermined voltage level, said predetermined voltage level occurring at a voltage level of said energy source which is intermediate said energy source first and second voltage levels, and the other of said resistance elements having a small temperature coefficient of resistance relative to the temperature coefficient of said one resistance element.

3. Protective apparatus for an electrical load device adapted for connection to a source of electrical energy having first and second voltage levels, said second voltage level being higher than said first voltage level, comprising a pair of parallel connected resistance elements serially connected with said energy source and said load device, one of said resistance elements having a positive temperature coefficient of resistance above a predetermined voltage level which is intermediate said energy source first and second voltage levels and the other resistance element having a temperature coefficient of resistance which is small relative to the temperature coefficient of said one resistance element, and a voltage dependent resis-

tor connected in parallel to said load device, said voltage dependent resistor exhibiting a sharply increasing conductivity above a predetermined voltage level intermediate said energy source first and second voltage levels.

4. Protective apparatus for an electrical load device adapted for connection to a source of electrical energy having first and second voltage levels comprising a pair of parallel connected resistance elements serially connected between said energy source and said load device, one of said resistance elements having a region exhibiting a substantially linear current versus voltage characteristic below a predetermined voltage level and having a negative resistance region above said predetermined voltage level, said predetermined voltage level being intermediate in value said energy source first and second voltage levels, and the other resistance element having a value of resistance which is substantially independent of temperature at said first and second voltage levels.

5. Protective apparatus for an electrical load device adapted for connection to a source of electrical energy having first and second voltage levels, said second voltage level being higher than said first voltage level, comprising first and second parallel connected resistance elements connected in series circuit with said energy source and said load device, said first resistance element having a substantially constant temperature coefficient of resistance at said first voltage level and a high positive temperature coefficient of resistance at said second voltage level, and said second resistance element having a resistance value substantially independent of temperature at said first and second voltage levels, said first resistance element undergoing a variation in resistance such that a substantially lower current flows therein at said second voltage level than flows therein at said first voltage level.

6. Protective apparatus for an electrical load device adapted for connection to a source of electrical energy having first and second voltage levels, said second voltage level being higher than said first voltage level, comprising first and second parallel connected resistance elements, a third resistance element connected in series circuit arrangement with said parallel connected resistance elements, the latter circuit being serially connected with said energy source and said load device, said first resistance element having a positive temperature coefficient of resistance above a first predetermined voltage level, said second resistance element having a temperature coefficient of resistance which is small relative to the temperature coefficient of said first resistance element, and said third resistance element having a positive temperature coefficient of resistance above a second predetermined voltage level which is higher than said first predetermined voltage level.

7. Apparatus for protecting an electrical load device adapted for connection to a source of electrical energy from an overload condition comprising first and second parallel connected resistance elements serially connected with said energy source and said load device, said first resistance element having a high positive temperature coefficient of resistance above a predetermined applied voltage level such that it exhibits a negative resistance characteristic above said voltage level, said second resistance element having a relatively small temperature coefficient of resistance, said first resistance element undergoing a sharply increasingly value of resistance above said voltage level thereby to limit the load current to said load device to a safe value in the event said predetermined voltage level is exceeded.

8. Apparatus as described in claim 7 wherein said load device comprises the armature of an electric motor and said overload condition results from a stalled condition of the motor.

9. Protective apparatus for an electrical load device adapted for connection to a source of electrical energy having first and second voltage levels, said second voltage level being higher than said first voltage level, comprising a pair of parallel connected resistance elements serially connected with said energy source and said load device, one of said resistance elements having a positive temperature coefficient of resistance above a predetermined voltage level and the other resistance element having a relatively small temperature coefficient of resistance at said first and second voltage levels, and a resistance element connected in parallel with said load device and having electrical resistance variations as determined by variations in the voltage applied thereto.

10. Apparatus as described in claim 9 wherein said voltage dependent resistance element has a high electrical resistance value upon applying a relatively low voltage thereto and a low electrical resistance value upon applying a high voltage thereto.

11. Protective apparatus for an electrical load device adapted for connection to a source of electrical energy having first and second voltage levels, said second voltage level being higher than said first voltage level, comprising first and second parallel connected resistors serially connected with said energy source and said load device, said first resistor exhibiting a positive resistance characteristic at said first voltage level and a negative resistance characteristic at said second voltage level, and said second resistor has a relatively small temperature coefficient of resistance.

12. Apparatus as described in claim 11 wherein said second resistor has a substantially fixed value of resistance which is substantially independent of temperature at said first and second voltage levels of said energy source.

13. Apparatus as described in claim 11 wherein said load device comprises the armature winding of an electric motor.

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ORIS L. RADER, *Primary Examiner.*