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# (54) Current limiting device

(57) A current limiting device 4 comprises a super-conducting material 6 arranged such that a current flowing in the device in excess of a predetermined value causes breakdown of the superconductivity of the super-conducting material. The device 4 is connected in series with a circuit breaker 3 so that when a short circuit occurs it limits the current in the circuit until the circuit breaker 3 has operated to open the circuit. A resistor 5 may be connected across the superconducting material 6 which may be a YBaCuO or BiSrCaCuO ceramic material. A magnetic field may be applied to the super-conducting material 6 by means of a solenoid 7 when a short circuit occurs.

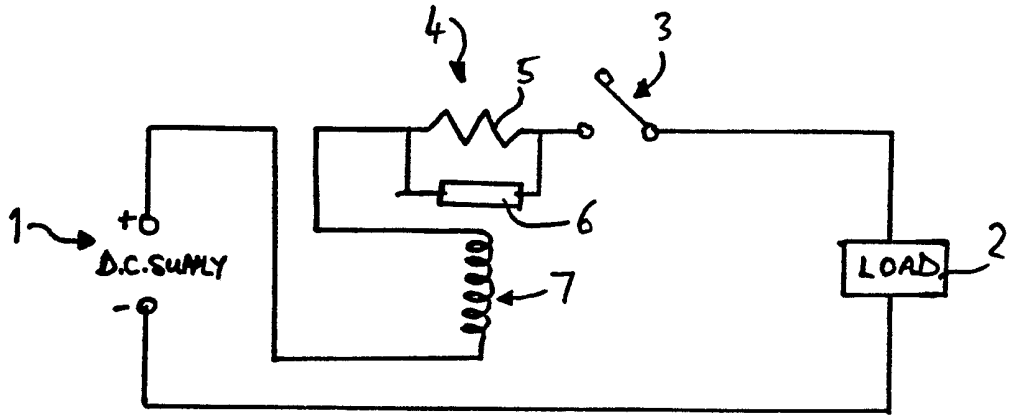


Fig. 2

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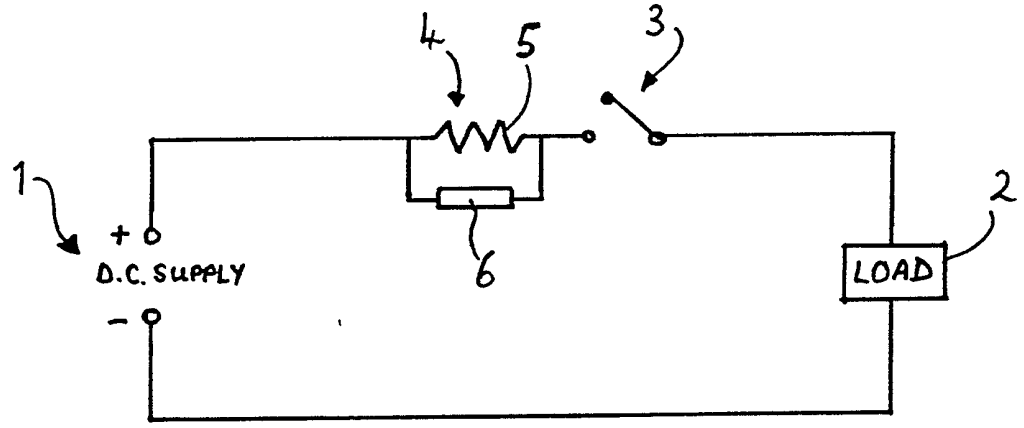


Fig. 1

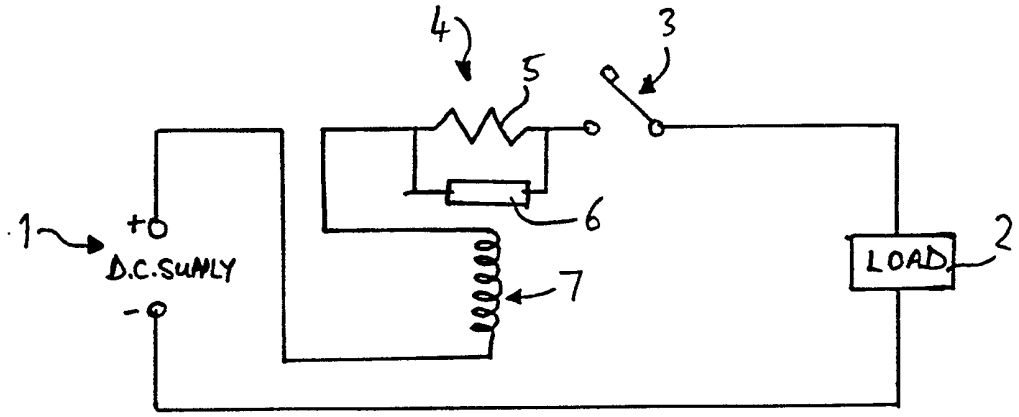


Fig. 2

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# CURRENT LIMITING DEVICE

This invention relates to a current limiting device particularly suitable for limiting current in a circuit breaker handling large direct currents.

Excess current activated DC circuit breakers handling high currents are typically of large dimensions, and require arrangements such as gas jets to extinguish any arc formed between the poles. Because of the size, the time taken to break the circuit maybe relatively long, for example up to 100 ms. During this time, the fault current in the circuit may continue to increase, thus making the breaking of the flow of current more difficult.

The present invention provides a device which can limit the current in the circuit until the circuit breaker operates.

According to the invention, a current limiting device comprises a superconducting material arranged such that a current flowing in the device in excess of a predetermined value causes breakdown of the super-

conductivity of the superconducting material.

Preferably a resistor is provided in parallel with the superconducting material to assist in controlling the flow of current when the superconductivity of the superconducting material has broken down. The device may include means for generating a magnetic field such that, when a current in excess of the predetermined value is passing through the device, a magnetic field is applied to the superconducting material in excess of the critical magnetic field thereof. Alternatively, or additionally, the material may be arranged such that a current in excess of the predetermined value passing through the device gives rise to a current density in the material in excess of the critical current density thereof.

The superconducting material is suitably a YBaCuO or BiSrCaCuO ceramic material wherein the relative proportions of the atoms are selected such that the material exhibits superconductivity above the boiling point of nitrogen, but other superconducting materials may also be employed.

The invention also provides an excess current

activated direct current circuit breaker, having connected in series therewith a current limiting device according to the invention.

Reference is made to the drawings, in which:

Figure 1 is a circuit diagram for a d.c. circuit incorporating a device according to one embodiment of the invention; and

Figure 2 is a circuit diagram showing the use of an alternative embodiment of the invention.

Referring first to Figure 1, the circuit comprises a DC supply 1, which may be a battery or a DC generator, for example, and which may have a polarity opposite to that shown. This supplies a load 2 which may, for example, be a motor. To protect the supply in the event of a short circuit, a current activated circuit breaker 3 is included. A current limiting device 4 in accordance with the invention is connected in series with the circuit breaker, and comprises a resistor 5 and a bar 6 of a YBaCuO or BiSrCaCuO class of ceramic superconducting material with associated liquid nitrogen cooling.

In the absence of the current limiting device 4, a short circuit in the load 2 causes the current flowing in the circuit to rise very rapidly. This means that the difficulty for the circuit breaker in actually breaking the flow of current is greatly increased in view of the length of time taken for the circuit breaker to operate. In the current limiting device 4 shown in Figure 1, the increase in the current in the circuit, substantially all of which flows through the superconducting element 6, the current density in the superconducting element 6 exceeds its critical current density and the material is no longer in a superconducting state. It therefore has a finite resistance, and in conjunction with the resistor 5 serves to limit the current flowing in the circuit until the circuit breaker has operated to open the circuit.

Referring now to Figure 2, the components of the circuit are essentially the same as in Figure 1 and are identified with the same reference numerals, with the exception of an additional solenoid 7, arranged to subject the superconducting material to a magnetic field while current is flowing through the circuit. In this case, if a short circuit occurs in the load 2, the rapid

rise in current in the circuit substantially increases the magnetic field due to the solenoid 7 until it exceeds the critical magnetic field, thereby causing the material to cease to be superconducting. Again, the resistance of the formerly superconducting material in conjunction with that of the resistor 5 limits the current flowing in the circuit.

The form of the superconducting element may be that of a bar, with the cooling material passed round the exterior of the bar, or it may be formed with pores or passageways passing therethrough, through which the liquid nitrogen may be passed to evaporate therein, thereby cooling the element.

Although reference is made to liquid nitrogen cooled superconducting materials, materials which are superconducting at higher temperatures may also be used in the device of the invention, with cooling arrangements adjusted accordingly.

CLAIMS

1. A current limiting device, comprising a superconducting material arranged such that a current flowing in the device in excess of a predetermined value causes breakdown of the superconductivity of the superconducting material.

2. A device according to Claim 1, wherein a resistor is connected in parallel with the superconducting material.

3. A device according to Claim 1 or 2 wherein the superconducting material is arranged such that current in excess of the predetermined value passing through the device gives rise to a current density in the material in excess of the critical current density thereof.

4. A device according to Claim 1, 2 or 3, comprising means for generating a magnetic field such that, when a current in excess of the predetermined value is passing through the device, a magnetic field is applied to the superconducting material in excess of the critical magnetic field thereof.

5. A device according to any preceding claim, wherein

the superconducting material is a YBaCuO or BiSrCaCuO ceramic material wherein the relative proportions of the atoms are selected such that the material exhibits superconductivity above the boiling point of nitrogen.

6. A device according to any preceding claim comprising means for cooling the superconducting material.

7. A current limiting device, substantially as described.

8. An excess current activated direct current circuit breaker, having connected in series therewith a current limiting device according to any preceding claim.

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