US005995392A

United States Patent [19]

Turner

[11] Patent Number: 5,995,392

[45] Date of Patent: Nov. 30, 1999

[54] **CURRENT LIMITER**

[75] Inventor: **Michael James Turner**, Leeds, United Kingdom

[73] Assignee: **Switched Reluctance Drives Limited**, Harrogate, United Kingdom

[21] Appl. No.: **08/986,053**

[22] Filed: **Dec. 5, 1997**

[30] **Foreign Application Priority Data**

Dec. 6, 1996 [GB] United Kingdom 9625434

[51] **Int. Cl.**[6] **H02H 9/00**

[52] **U.S. Cl.** **363/49**; 323/908; 361/58

[58] **Field of Search** 363/49, 77; 323/294, 323/908; 361/58, 91.5

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,112,435	11/1963	Barney	361/58
3,935,511	1/1976	Boulanger et al.	317/20
4,450,496	5/1984	Doljack et al.	361/58
4,652,963	3/1987	Fahlen	361/58
4,769,752	9/1988	Rackowe	363/56
5,187,653	2/1993	Lorenz	363/89
5,305,174	4/1994	Morita et al.	361/58
5,350,997	9/1994	Ghotbi et al.	363/49
5,420,780	5/1995	Berstein et al.	323/908
5,574,632	11/1996	Pansier	363/49
5,737,160	4/1998	Duffy	361/58
5,737,161	4/1998	Thomas	361/58

FOREIGN PATENT DOCUMENTS

1 375 605	11/1974	United Kingdom .
2 300 982	11/1996	United Kingdom .
WO 97/10635	3/1997	WIPO .
WO 97/10637	3/1997	WIPO .

OTHER PUBLICATIONS

Ellegård, Kristen, "Inrush Current Limiter," Electronics World and W.W., Jul. 1994, p. 601.

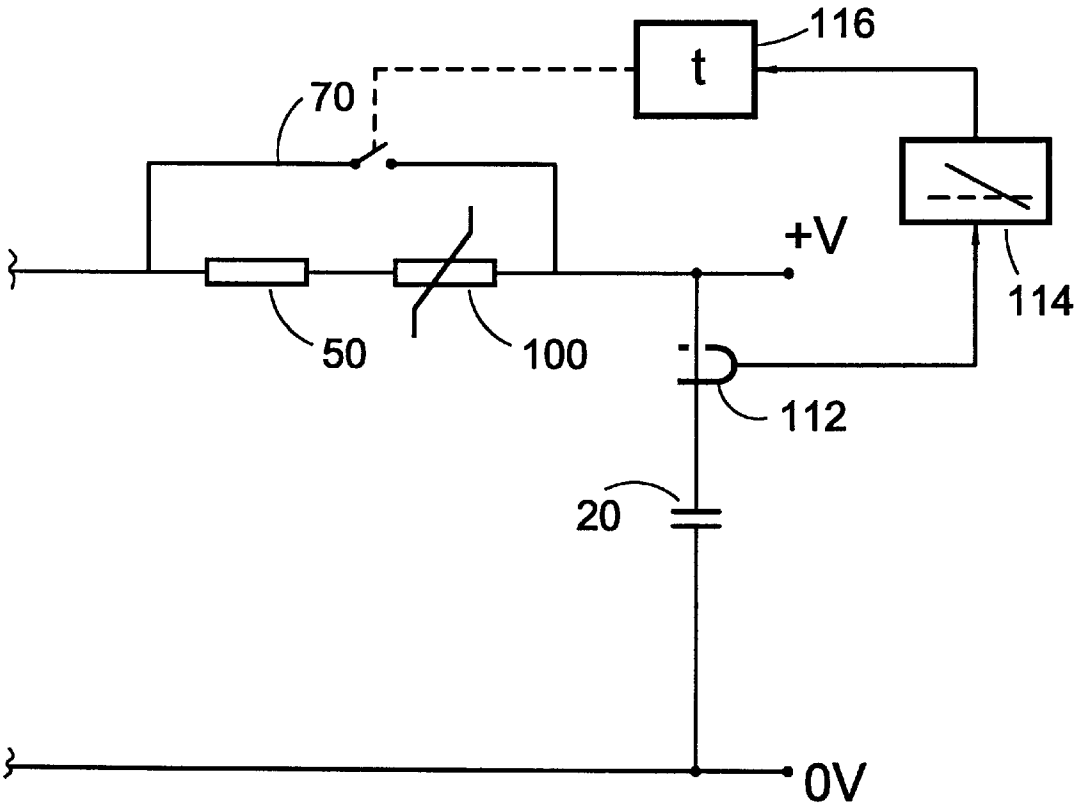
Primary Examiner—Adolf Deneke Berhane

Attorney, Agent, or Firm—Patterson & Keough, P.A.

[57] **ABSTRACT**

A current limiter for a rectifier circuit includes a fixed resistor **50** and a positive temperature coefficient (PTC) resistor **100** connected in series across a control switch **70**. The control switch is connected between a rectifier output and a smoothing capacitor **20**. If the switch fails to operate, the PTC resistor heats up, increasing its resistance in the presence of an abnormal current. The increased resistance will limit the current supplied to the rectifier output terminals **40**.

15 Claims, 3 Drawing Sheets



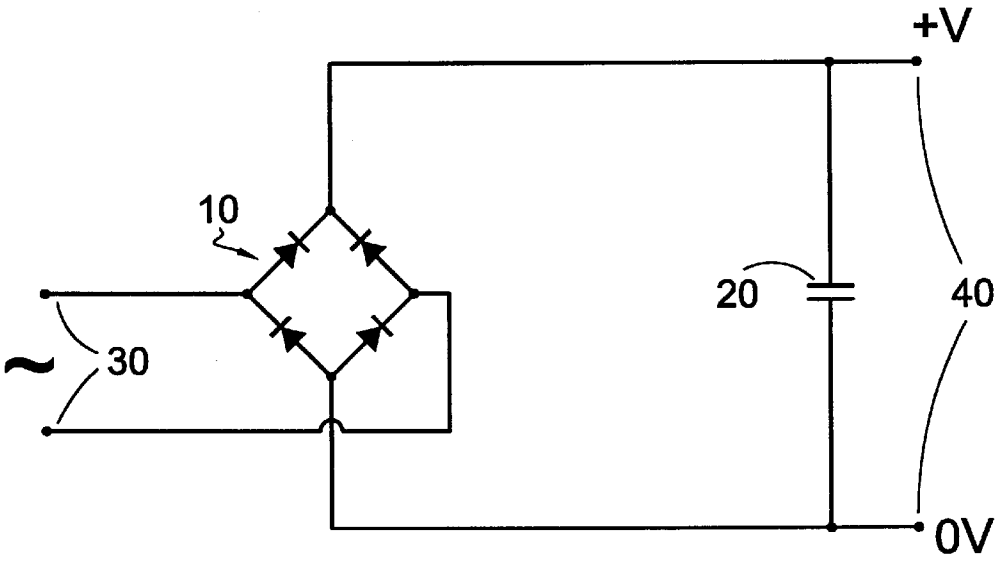


Fig 1

(Prior Art)

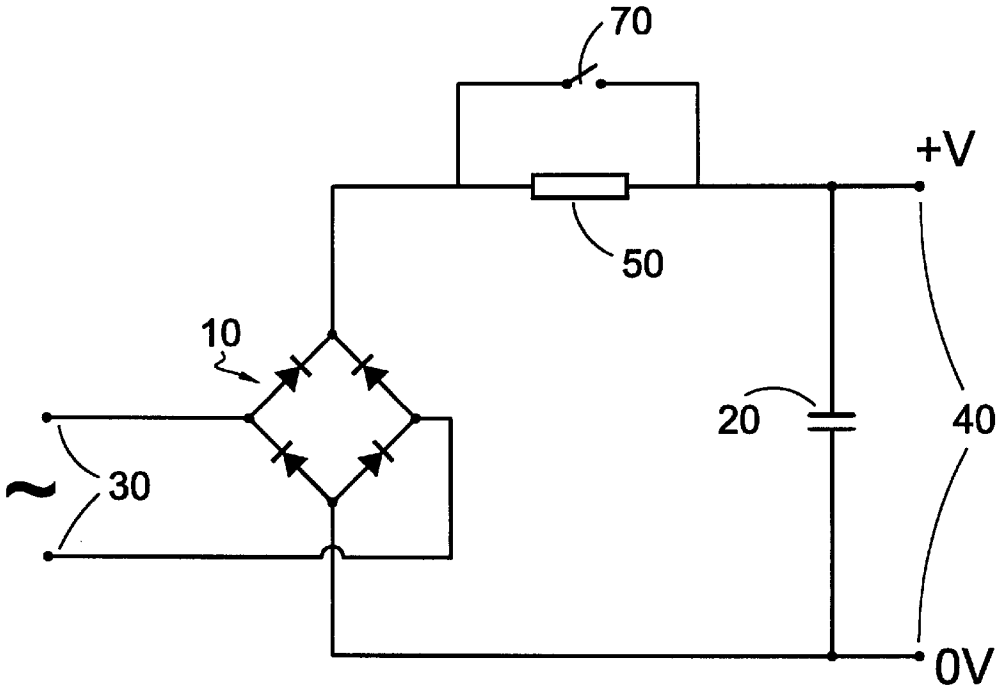


Fig 2

(Prior Art)

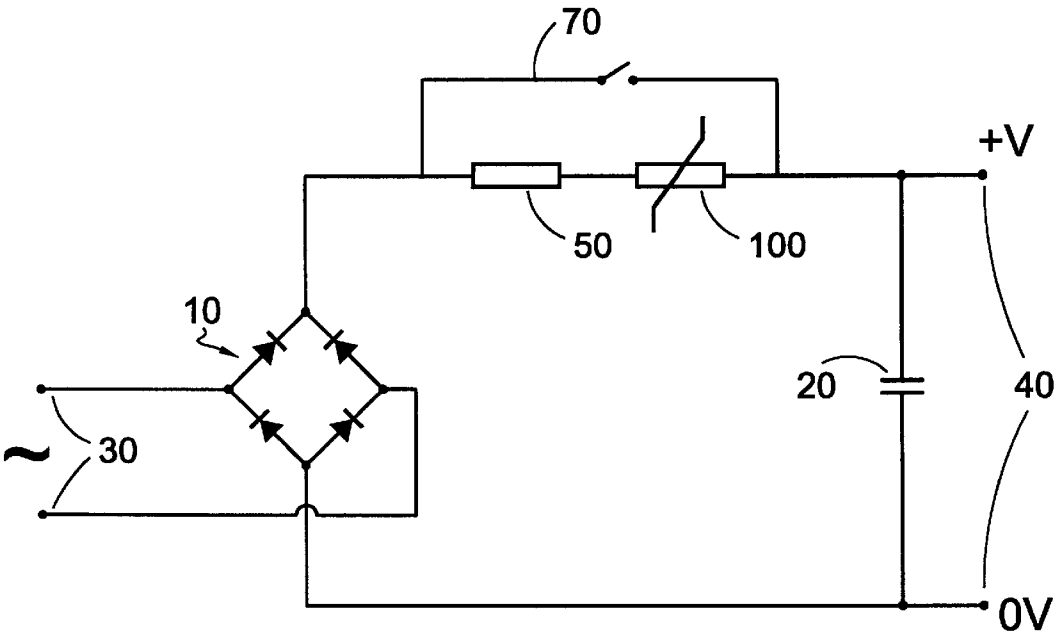


Fig 3

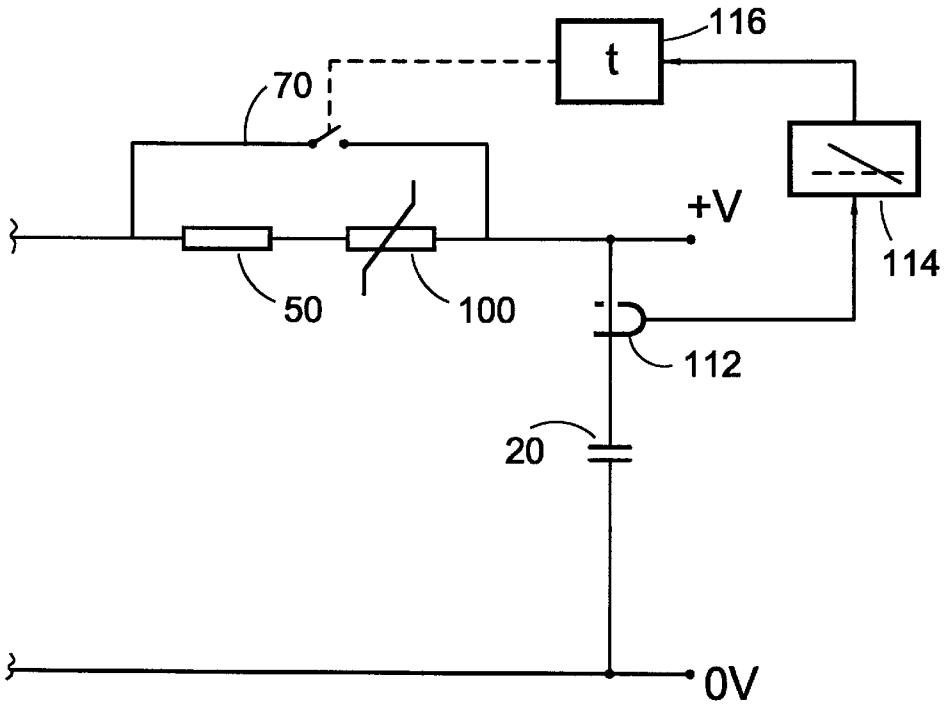


Fig 4

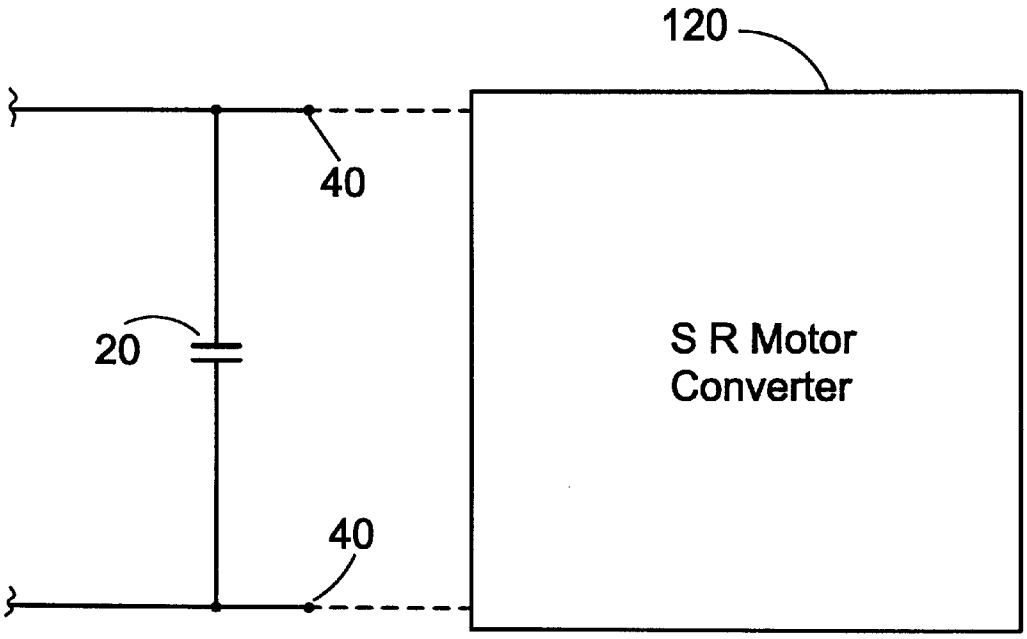


Fig 5

CURRENT LIMITER

BACKGROUND OF INVENTION

1. Field of Invention

This invention relates to current limiters, and particularly, but not exclusively, to current limiters for rectified power supplies.

2. Description of Related Art

FIG. **1** shows a rectifier circuit for converting an alternating current (a.c.) input into a rectified and smoothed direct current (d.c.) output. The circuit comprises a bridge rectifier **10** which produces a full-wave rectified output from the a.c. input which is applied across terminals **30**. The full wave rectified output of rectifier **10** is smoothed by means of a capacitor **20** to provide the circuit output across terminals **40**. In a practical application, a load requiring a d.c. input would be connected across the terminals **40**.

When the a.c. supply is first switched on, the capacitor **20** is uncharged and a very high current is initially drawn as the capacitor charges. This in turn may damage the components of the circuit, particularly the diodes of the rectifier **10**. In addition, the current surge reflected into the supply is often unacceptable. In order to prevent this, it has been proposed to connect a switch in the circuit between the rectifier and the capacitor, with a resistor in parallel with the switch. Such a circuit is shown in FIG. **2**. The switch **70** is held open when the a.c. supply is switched on, and the rectified current is then forced to flow through the resistor. Thus, only a proportion of the total e.m.f. available is dropped across the capacitor **20**, thereby limiting the amount of current drawn as the capacitor charges. After a period, the voltage across the capacitor rises to some suitable level as the capacitor charges and the switch can be closed. This process is commonly called 'soft starting'. A modification of this well-known arrangement is shown in U.S. Pat. No. 5,087,871, which is incorporated herein by reference.

One problem with such a circuit is that if the capacitor **20** is faulty, the charge it stores may never be sufficient to create a significant voltage drop across it. Alternatively, the load to which the circuit output at the terminals **40** is connected may malfunction, causing abnormally large currents to be drawn and preventing the normal working voltage across the capacitor from being established. In either case, the high current drawn through the resistor **50** will not decrease sufficiently to allow the switch **70** to be closed. Significant current will then be drawn through the resistor **50** for a prolonged period, causing it to get very hot and at least pose a fire risk if not actually to catch fire itself.

A second problem is that the switch **70** may become stuck in the open circuit condition. This would also cause the normal load current to flow through the resistor for extended periods with the associated fire risk.

A further problem is that users of the equipment may cause the resistor **50** to overheat by repeatedly discharging the capacitor, then charging again using this circuit. The resistor **50** will typically be chosen to comfortably accommodate the energy dissipated in one charging cycle. However, it then requires a significant period of time to cool before the charging sequence can be repeated. Repeated cycling (e.g. by the user switching the input on and off too rapidly and repeatedly) may cause the resistor to overheat.

European published patent application number 667666, which is incorporated herein by reference, shows a circuit having detection means which detects if the switch is closed prior to switching on the a.c. supply to the rectifier **10**. If it is, the circuit is prevented from operating. Although this arrangement precludes high start-up currents from occurring accidentally, it does not address the more serious problem which arises when, for example, the capacitor is unable to store charge properly or a load draws excessive current, nor when the switch is unable to close in the first place.

It is an object of the present invention to provide a circuit which at least alleviates these problems of the prior art.

SUMMARY OF THE INVENTION

According to embodiments of the present invention there is provided a current limiter comprising first and second terminals, a first resistor connected in series with a second resistor between the terminals, and switch means connected in parallel with the resistors between the terminals, characterized in that the second resistor is a thermistor having a positive temperature coefficient, the thermistor being responsive to an abnormal current, above a working current through the resistors, while the switch means is open, to cause its resistance to increase, thereby limiting the magnitude of the current above the working current.

It will be realized that this circuit uses the PTC thermistor in an unconventional way. Normally the PTC thermistor is expected to cycle over a resistance range in response to a working current. By contrast, in the circuit of embodiments of the present invention, the PTC thermistor is designed to pass the initial working current, which will include an initial surge current, without any significant change in resistance. It is only if a fault occurs in the components associated with the circuit, or if the circuit is operated in such a way that damage due to prolonged exposure to excessive currents occurs, that the PTC thermistor will react and reduce the current to a safe level.

It will be appreciated that the components of the circuit of FIG. **3**, described in more detail below, will be rated according to an expected working current. The invention provides protection for the circuit in the presence of an abnormal current, for example a fault current or, in the event of abnormal operation by a user, an excessive current for a prolonged period.

The thermistor provides a backup protection for the first resistor in the event that the switch fails to close when required to do so. Any prolonged exposure to the high current causes the thermistor to heat up such that its resistance rises rapidly and limits the current flowing in the circuit. The thermal inertia of the thermistor may also assist in alleviating the problem of repeated cycling of the circuit. Multiple charging operations with insufficient cooling intervals between them will cause the PTC thermistor temperature to rise to the point where its resistance increases sharply, thereby again protecting the resistor **50** from overheating.

A PTC thermistor is typically a semiconductor device, including barium titanium oxide. Other types are also available. They are supplied by electronic component manufacturers, e.g. Philips Components Limited, London, England as the 2322 Series of PTC resistors. A PTC resistor is distinguished from a standard wire-wound or carbon resistor by having an initially relatively low resistance which rises rapidly with temperature.

The switch may for example be a relay, a thyristor or other semiconductor switching device.

Preferably, the switch is arranged to close once the magnitude of the current surge has subsided and the voltage across capacitor **20** has reached a predetermined value. Once the current surge has passed, closing the switch provides a short circuit for the current, substantially preventing it from

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS
Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS
Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS
Sync your system to PACER to automate legal marketing.