

93P3483P

- 1 -

AC power controller

REPLACED SHEETS SG

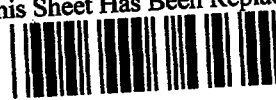
- ☒ Description : paged ..2... to paged
- ☒ Claim(s) : paged ..7... to paged
- ☐ Drawing(s) : paged to paged
- ☐ Abstract : paged to paged

The invention relates to an AC power controller, which operates at least with two reverse-connected series semiconductor regions. The semiconductor regions, which are each provided with an electron donor (source), an electron sink (drain) and an electrode (gate) which controls the flow of electrons, have the same characteristic curves as FETs. According to contemporary knowledge, they also have an internal body diode, dictated by the technology, in the inverse mode.

A known power circuit-breaker (WO 93/11608) operates with two reverse-connected series FETs, in the case of which power circuit-breaker the release element of a component acting as a relay is arranged electrically in parallel with a semiconductor element having two reverse-connected series FETs, which component can interrupt a line train to be protected by means of interrupter contacts. In that case, the semiconductor element is set in such a way that its internal impedance has a low value when there is a specific control voltage across a control electrode and an operating voltage across working electrodes situated in the direction of continuity in a line train, and its internal impedance rises abruptly as the voltage across the working electrodes rises. In the event of an increase in the internal impedance, voltage is applied to the release element arranged in parallel, which voltage results in tripping.

Electrical installations have to be connected to and isolated from an electricity supply. In the case of mechanical switches, there are optimized solutions which in practice satisfy the technical requirements, for example in the case of drives, motor protective circuit-breakers, in respect of overload protection and short-circuit protection. It is generally desirable in the case of protective switchgear, which include power circuit-breakers, motor protective circuit-breakers or line protective circuit-breakers, rapidly to detect overload currents that occur, in particular short-circuit

3-0857038



93P3483P

- 2 -

currents, and to limit them to small values and finally to disconnect them. Mechanical protective switchgear have the disadvantages of contact wear, frequent maintenance and a comparatively slow switching time in the event of
5 a short circuit as well as comparatively low temporal accuracy of the switching instance.

In contrast, semiconductor switches can operate without any wear and switch rapidly; they have low switching losses and they can be controlled in a variable
10 manner. On the other hand, the disadvantages of semiconductor switches are: high costs, high space requirement and comparatively high forward losses.

In general terms, it is frequently desirable to limit alternating currents rapidly to specific values, so
15 that overcurrents become tolerable or in order that to the [sic] time remains for disconnection. Semiconductor element [sic] can also be operated in such a way that they reduce a current all the way down to the point of disconnection.

20 The invention is based on the object of developing an advantageous AC power controller using semiconductor technology. The invention is at the same time based on the knowledge that the previously outlined devices and elements can be designed as AC power controllers in the
25 broadest sense.

The object that has been outlined is achieved according to the invention by means of an AC power controller according to Patent Claim 1. In this case, with reverse-connected series semiconductor regions, the
30 gate-source voltage at the respective semiconductor region in the forward direction are [sic] set to be large enough for a desired limiting of the drain-source current to be established. At the semiconductor region in the inverse mode, the respective gate-source voltage is
35 only set to be large enough for the body diode to remain de-energized. The invention is based on the knowledge here that the forward losses in relevant semiconductor elements is [sic] composed of the losses in the switching element and of the losses of additional freewheeling

diodes which are frequently connected in series. Special freewheeling diodes are not necessary in the AC power controller, since bipolar conductivity mechanisms and stored charges connected therewith do not occur. Therefore, separate freewheeling diodes are not required, nor does the body diode, which is a condition of the semiconductor technology, come into effect. The AC power controller therefore operates with particularly low steady-state and dynamic losses. Steady-state losses include the losses during current continuity and dynamic losses include switching-over losses.

If the semiconductor regions are formed from silicon carbide, SiC, this yields particularly large and favourable operating ranges in the family of characteristic curves. The semiconductor regions can be formed in a microchip or alternatively be designed as discrete FETs.

The invention will now be explained in more detail using exemplary embodiments which are represented in a roughly diagrammatic form in the drawing.

Figure 1 illustrates an AC power controller.

Figure 2 illustrates, for a semiconductor region, the drain-source current, I_{DS} , against the drain-source voltage, U_{DS} , for parameters with the gate-source voltage, U_{GS} , in the vicinity of the origin for two reverse-connected series regions.

Figure 3 illustrates, on a different scale with the inclusion of higher drain-source voltages, a family of characteristic curves for I_{DS} on the ordinate and on [sic] U_{DS} on the abscissa for reverse-connected series semiconductor regions.

The AC power controller according to Figure 1 operates with two reverse-connected series semiconductor regions 1 and 2, which are represented as discrete FETs in the exemplary embodiment. Each semiconductor region has a source 3, a drain 4 and a gate 5. In the forward direction, for example at the semiconductor region 1, the gate-source voltage 6, U_{GS1} , is set to be large enough for a desired limiting of the drain-source current to be established. The gate-source voltage is in this case a

parameter for current limiting lines such as those illustrated in Figure 3. At the semiconductor region in the inverse mode, let it be the semiconductor region 2 in the exemplary embodiment according to Figure 1, the gate-source voltage 7, $U_{GS\ 2}$, is only set to be large enough for the body diode 8 to be de-energized. In the case of FET made of silicon carbide, the threshold voltage is approximately 2.8 V, for example. In the case of silicon, threshold voltages of approximately 0.7 V are customary.

10 The gate-source voltage at the semiconductor region 2 is then to be set in such a way that the voltage drop across the operating path is lower than the threshold voltage of the body diode.

The semiconductor regions 1 and 2 can be formed from silicon carbide and be implemented, in particular, in a microchip. The semiconductor regions can also be designed as discrete FETs, in particular as MOSFETs.

In the case of the AC power controller according to Figure 1, gate driving suffices for both semiconductor regions 1, 2 in both current directions, although at potentials of different magnitude. For an applied voltage U, the AC power controller sets a current I to a desired value in the family of operating characteristic curves, as a function of the gate-source voltage 6, 7.

25 In the case of a semiconductor region having characteristic curves such as those exhibited by FETs, characteristic curves according to Figure 2 are produced at small drain-source voltages for reverse-connected series semiconductor regions. With an increasing gate-source voltage, U_{GS} , as the parameter, the characteristic curves starting at the origin tend to follow the straight line 9, R_{ON} to a greater and greater extent. Viewed another way, a steep characteristic curve for the ON resistance, that is to say a very low ON resistance, is achieved at high gate-source voltages. This characteristic curve, which is to be interpreted as the resistance, exhibits a linear, in other words ohmic, behaviour. With reverse-connected series circuitry, the characteristic curves and R_{ON} extend in the first and third quadrants.

In the case of silicon carbide, for example, the voltage drop in the forward direction caused by R_{ON} is distinctly lower than the threshold voltage of the body diode.

Figure 3 illustrates, on a different scale, a family of characteristic curves after the manner of Figure 2 reaching to higher drain-source voltages and parameters with a higher gate-source voltage. Characteristic curves which limit the drain-source current are produced approximately parallel to the abscissa for gate-source voltages. For the sake of simplicity, it will be assumed that enhancement-mode FETs are used for the semiconductor regions, these being normally off and having an n-channel. The illustration in Figure 1 corresponds to this. The body diodes 8 produce a superposition with a characteristic curve 11 in the first and third quadrants. Operation on the characteristic curve 11, which illustrates that the body diode in parallel with the operating path of the semiconductor region becomes effective in the reverse direction, can be avoided by setting the gate-source voltage at the semiconductor region in the inverse mode only to be large enough for the body diode to remain de-energized, in other words, therefore, by remaining in an operating region between the abscissa and the limiting line 12 through the point of intersection between the R_{ON} resistance 9 and the characteristic curve 11 for the body diode. This avoids bipolar conductivity mechanisms in any operating mode, so that stored charges do not occur, as a result of which the steady-state and dynamic losses of the AC power controller are kept low.

A desired drain-source current can be set in the event of overvoltages by means of a suitable gate-source voltage as the parameter in the family of characteristic curves according to Figure 3. During normal operation of the AC power controller, only low losses occur corresponding to the characteristic curve 9 for the R_{ON} resistance, which losses are lower, the more steeply the characteristic curve 9 proceeds. In the case of silicon carbide and particularly in the case of a structure after

the manner of a MOSFET, it is possible to effect current limiting, for example, approximately between 300 and 5000 V for the voltage U according to Figure 1. The respective gate-source voltage can be generated by a drive circuit 10 according to Figure 1 in a manner known per se. If the gate-source voltage at the respective semiconductor region in the inverse region [sic] is set only to be large enough for the body diode of the relevant semiconductor region to remain de-energized, separate freewheeling diodes are not required to lower the dynamic losses, since essentially they do not occur at all.

The AC power controller described here can be used in a very wide variety of applications. Thus, it can be used, for example, as a special limiter in series with commercially available protective circuit-breakers, the current being limited in the limiter to a specific value in the event of overvoltages. During rated operation, on the other hand, it has such a low resistance that the steady-state losses remain low. However, the AC power controller can also be designed as a circuit-breaker which, in the event of overvoltages, given an appropriate gate-source voltage initially limits the current to a predetermined amount and, given correspondingly continually lowered gate-source voltages, is reduced [sic] the current. The AC power controller can also be used generally to set a specific current I in an operating range, independently of the voltage U .



Patent Claims

1. AC power controller, which operates at least with two reverse-connected series semiconductor regions (1, 2), each having an electron donor (3; source), an electron sink (4; drain) and an electrode (5; gate) which controls the flow of electrons, and characteristic curves such as those exhibited by FETs, in other words also having an internal body diode, dictated by the technology, the gate-source voltage (6; 7) at the respective semiconductor region (1; 2) in the forward direction being set to be large enough for a desired limiting of the drain-source current to be established, and the gate-source voltage (7; 6) at the respective semiconductor region the respective in the inverse mode (2; 1) being set only to be large enough for the body diode 8 to remain de-energized.
2. AC power controller according to Claim 1, characterized in that the semiconductor regions (1, 2) are formed from silicon carbide (SiC).
3. AC power controller according to Claim 2, characterized in that the semiconductor regions (1, 2) are formed in a microchip.
4. AC power controller according to Claim 2, characterized in that the semiconductor regions (1, 2) are designed as discrete FETs.

This Sheet Has Been Replaced



93P3483P

Abstract

AC power controller which operates at least with two reverse-connected series semiconductor regions (1, 2).

Each semiconductor region (1; 2) has an electron donor (3; source), an electron sink (4; drain) and an electrode (5; gate) which controls the flow of electrons, in conjunction with characteristic curves such as those exhibited by FETs. The semiconductor region also has internal body diodes, dictated by the technology. It is provided that the gate-source voltage (6; 7) at the respective semiconductor region (1; 2) in the forward direction is set to be large enough for a desired limiting of the drain-source current to be established. The gate-source voltage (7; 6) at the semiconductor region in the inverse mode (2; 1) is set to be large enough for the body diode (8) to remain de-energized.

FIG 1

1/2

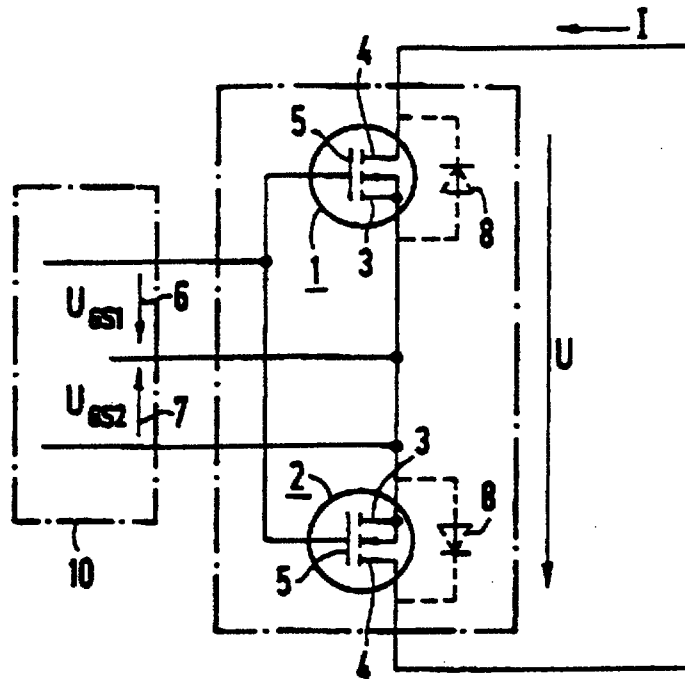


FIG 1

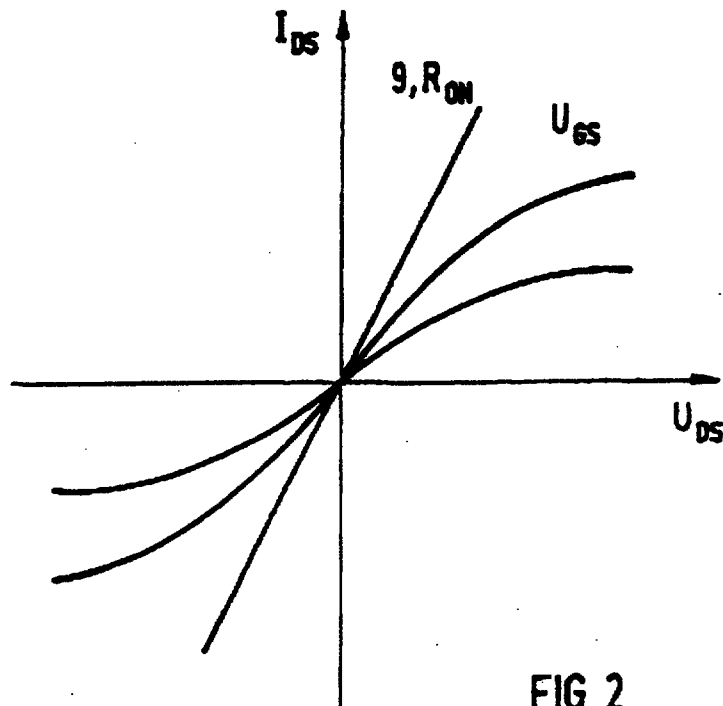


FIG 2

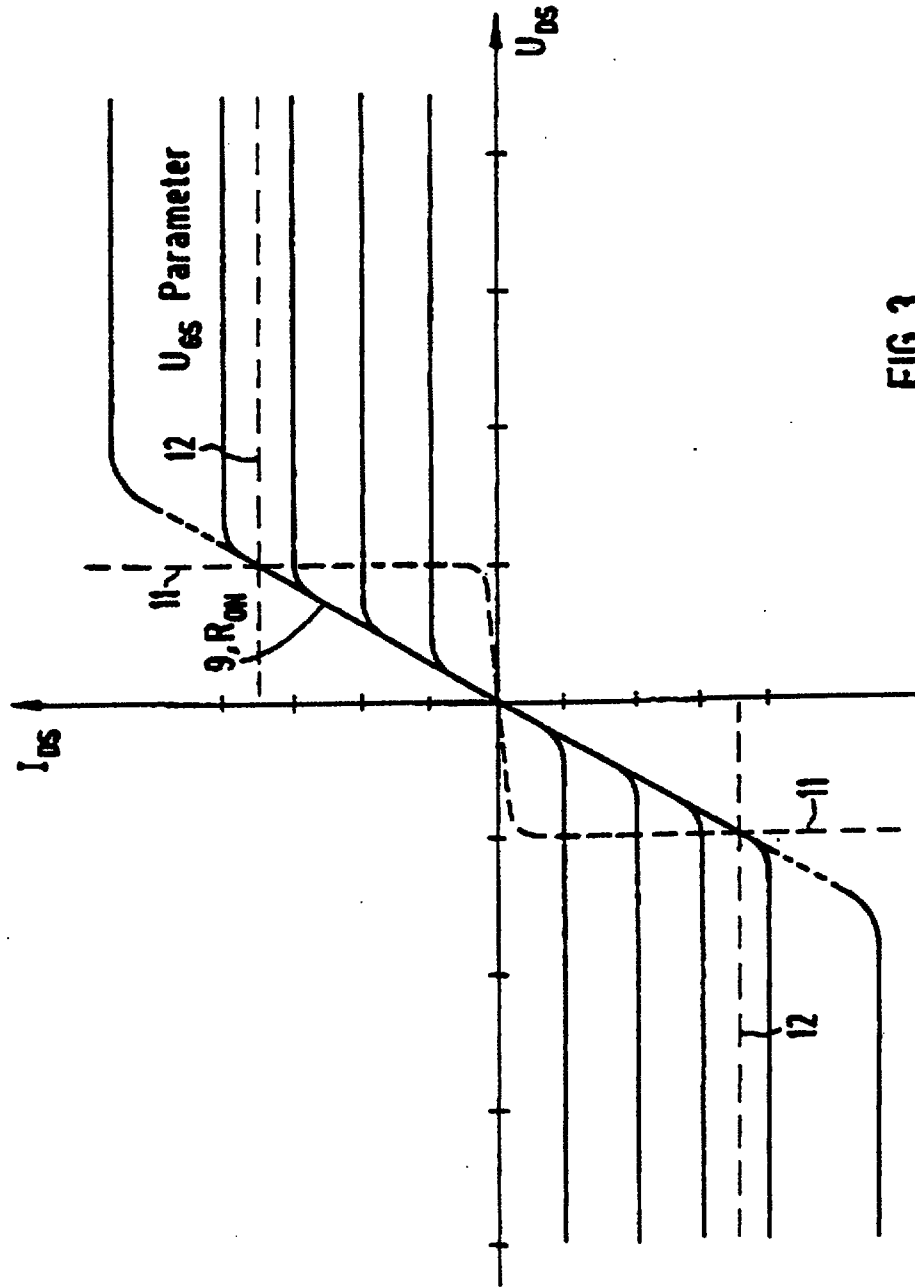


FIG 3

- 2 -

currents, and to limit them to small values and finally to disconnect them. Mechanical protective switchgear have the disadvantages of contact wear, frequent maintenance and a comparatively slow switching time in the event of a short circuit as well as comparatively low temporal accuracy of the switching instance.

5

In contrast, semiconductor switches can operate without any wear and switch rapidly; they have low switching losses and they can be controlled in a variable manner. On the other hand, the disadvantages of semiconductor switches are: high costs, high space requirement and comparatively high forward losses.

10

In general terms, it is frequently desirable to limit alternating currents rapidly to specific values, so that overcurrents become tolerable or in order that the time remains for disconnection. Semiconductor element can also be operated in such a way that they reduce a current all the way down to the point of disconnection.

15

The invention is based on the object of developing an advantageous AC power controller using semiconductor technology. The invention is at the same time based on the knowledge that the previously outlined devices and elements can be designed as AC power controllers in the broadest sense.

20

Accordingly, this invention provides an AC power controller, configured to operate with at least two, reverse-connected semiconductor regions or devices in series, each of which is provided with an electron donor, an electron sink and an electrode which controls the flow of electrons, said regions or devices also having characteristic curves such as those exhibited
25 by FETs, in other words also having an internal body diode, dictated by the technology,

the first semiconductor region or device being operated in a forward direction, having a gate-source voltage selected to limit a current of the AC power controller to a predetermined value, and

the gate-source voltage of the second semiconductor region or device being operated
30 in an inverse mode, wherein

This is the replacement sheet

Date: 11 APR 1998

REPLACEMENT SHEETS		SG
☒	Description	: paged 2... to paged 2...A
☒	Claim(s)	: paged 2... to paged 2...
☐	Drawing(s)	: paged to paged
☐	Abstract	: paged to paged
DATE OF RECEIPT 13/4/98		

- 2A -

the predetermined value of the AC power controller current of the first semiconductor region or device is selected so that the second semiconductor has at this current, a voltage drop so that a body diode of said second region or device is still de-energized.

- 5 In this case, with reverse-connected series semiconductor regions, the gate-source voltage at the respective semiconductor region in the forward direction are set to be large enough for a desired limiting of the drain-source current to be established. At the semiconductor region in the inverse mode, the respective gate-source voltage is only set to be large enough for the body diode to remain de-energized. The invention is based on the
- 10 knowledge here that the forward losses in relevant semiconductor elements is composed of the losses in the switching element and of the losses of additional freewheeling

This is the replacement sheet

Date: 11 APR 1998



THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An AC power controller, configured to operate with at least two, reverse-connected semiconductor regions or devices in series, each of which is provided with an electron donor,
5 an electron sink and an electrode which controls the flow of electrons, said regions or devices also having characteristic curves such as those exhibited by FETs, in other words also having an internal body diode, dictated by the technology,
the first semiconductor region or device being operated in a forward direction, having a gate-source voltage selected to limit a current of the AC power controller to a predetermined
10 value, and
the gate-source voltage of the second semiconductor region or device being operated in an inverse mode, wherein
the predetermined value of the AC power controller current of the first semiconductor region or device is selected so that the second semiconductor has at this current, a voltage
15 drop so that a body diode of said second region or device is still de-energized.
2. An AC power controller according to Claim 1, wherein the semiconductor regions or devices are formed from silicon carbide (SiC).
- 20 3. An AC power controller according to Claim 2, wherein the semiconductor regions are formed in a microchip.
4. An AC power controller according to Claim 2, wherein the semiconductor devices are designed as discrete FETs.

25