

Description

Electronic circuit breaker

The invention relates to an electronic circuit breaker with a semiconductor switch, the source connection and drain connection of which are connected between a voltage input and a load output, and the gate connection of which is connected to a control unit, which is supplied at the input end with a signal representing the load current.

An electronic switch or circuit breaker of this type is known, for example, from DE 203 02 275 U1. The electronic switch has a semiconductor switch in the form of a MOSFET (metal-oxide-semiconductor field-effect transistor), which is connected in a current path between an operating voltage connection and a load connection. To achieve reliable current limitation in a direct voltage network, a measured value, detected by a current sensor in the current path, is supplied to a comparator input of a control device. When a switch-on signal is present and at a measured value that falls below a reference value, the control device biases the semiconductor switch into conduction, whereas at a measured value that exceeds the reference value, the control device biases the power transistor to cut-off and limits the current flowing across it to the reference value.

A power distribution system in the low-voltage range, in particular, in the 24 V DC range, having a number of circuits each having an electronic circuit breaker as short-circuit protection and/or overload protection, is known from EP 1 186 086 B1. The circuits are jointly supplied by a clocked power supply unit. In the event of an overload when an adjustable threshold is exceeded, e.g., by 1.1 times the rated current (I_N), the electronic circuit breaker is switched off after the delay time has expired, whereas in the event of a short circuit, a current limitation occurs first and after a further threshold (e.g., $2 \times I_N$) is exceeded, the circuit breaker is switched off after a specific turn-off time has expired.

An electronic circuit breaker, which is triggered by a microprocessor via a trip circuit and interrupts the power supply to a load with a time delay, is known from EP 1 150 410 A2. A partial interruption of the circuit breaker occurs beforehand or simultaneously.

A partial interruption of an electronic circuit breaker with a plurality of switch blocks, each of which have an electronic switch in the form of a MOSFET and a comparator controlling it via a joint microprocessor, is also known from EP 1 294 069 B1. In the case of an overcurrent, the power supply to the load is interrupted after a time delay, which follows a partial inhibition of the at least one switch.

The semiconductor switch of the electronic circuit breaker is utilized as a constant current source for charging the capacitor for switching particularly capacitive loads and/or for the protection thereof from overcurrent and short circuit. The semiconductor switch and in particular a MOSFET employed hereby must be able to support the power dissipation as a result of the inrush current during the switching or during the charging of the capacitor. Because of this situation, electronic circuit breakers, in particular those with a constant current limitation, are usually designed with an overdimensioned semiconductor switch (MOSFET) to adequately take into account this power dissipation. A dimensioning of this type of employed semiconductor switch leads to increased expenditures, however, and a correspondingly large space requirement within the circuit of the electronic circuit breaker.

An alternative option is to undertake a clocked driving of the semiconductor switch by means of pulse width modulation (PWM). However, this increases not only the driving outlay. Rather, PWM driving leads to problems in the case of inductive loads.

The object of the invention is to provide an electronic circuit breaker operating as effectively as possible while avoiding the named disadvantages. In particular, an overdimensioned semiconductor switch and its costly driving should be avoided in this case.

Furthermore, a suitable method for operating such an electronic circuit breaker is to be provided. An operating method of this type is to be understood in particular as a suitable driving method for controlling and/or regulating the semiconductor switch of such an electronic circuit breaker, in particular during a switch-on process for a load.

In regard to the electronic circuit breaker, the aforementioned object is attained according to the invention by the features of claim 1. Advantageous embodiments and refinements are the subject of the claims dependent thereon. In regard to the operating or driving method, the aforementioned object is attained according to the invention by the features of claim 7. Advantageous refinements are the subject of the claims dependent thereon.

It is provided to this end that a control or regulating device, which is connected to the gate connection of a semiconductor switch, connected between a voltage input and a load output, determines the drain-source voltage of the semiconductor switch, and generates a gate signal for the semiconductor switch from said voltage and from the detected load or semiconductor current (drain-source current), and on the basis of the signal the power of the semiconductor switch is adjusted to be less than or equal to a maximum power value.

The invention is based in this regard on the premise that during the charging process of a capacitive load a dynamic current limitation is utilized, which in contrast to a constant current limitation is not set to a specific threshold value but depends on the actual value of the drain-source voltage of the semiconductor switch (MOSFET) and changes dynamically with the proviso that the relationship between the current actually flowing across the semiconductor switch (drain-source current) and the drain-source voltage is always kept within a safe operating range of the semiconductor switch. The current control in this case can occur by analog means or with the use of a microprocessor.

Because due to this active current control, the power dissipation of the semiconductor switch can be controlled in a regulated manner, the semiconductor switch accordingly

can be dimensioned smaller with respect to the predominant power dissipation. Because in addition this type of power control of the semiconductor switch is virtually independent of the gate signal waveform, inductive loads can also be reliably switched and protected.

The drain-source voltage of the semiconductor switch can be determined either directly or derived from available voltage values. Therefore, the drain voltage of the semiconductor switch or the input voltage of the electronic circuit breaker and the source voltage of the semiconductor switch or the output-side load voltage of the electronic circuit breaker are advantageously detected and supplied as the respective voltage value to the control unit. The unit determines the drain-source voltage of the semiconductor switch therefrom, in particular by difference formation.

The measured current value used for power adjustment of the semiconductor switch, in particular during a switch-on process of the electronic circuit breaker, due to the series connection of the semiconductor switch with the load, corresponds to the load current flowing across it, which is detected by a current sensor in the current path of the semiconductor switch and the load. The power adjustment of the semiconductor switch then occurs by the formation of the product of the detected or determined drain-source voltage and the load current. In this case, the semiconductor switch is triggered via its gate connection such that its power is less than or equal to a specific, maximum power value, for example, 50 W.

Advantageously, the electronic circuit breaker is designed in addition with a constant current limitation so as to limit the current flowing across the load in the event of an overload and/or short circuit to a specific, predetermined current threshold value.

An exemplary embodiment of the invention will be described in greater detail hereinafter using a drawing. In the drawing:

- FIG. 1 in a block diagram shows an electronic circuit breaker with a controlled semiconductor switch in the positive path of a current control and with a control unit, set up and provided for its power control, in the form of, for example, a microprocessor;
- FIG. 2 in a current/voltage time diagram shows the load current and load voltage profile as a result of the power control of the semiconductor switch during a switch-on process of a particularly capacitive load in the case of a stepped or step-like increase in the current; and
- FIG. 3 in a diagram according to FIG. 2 shows the current and voltage profile in the case of a ramp-like increase in the current.

Parts and parameters corresponding to one another are provided with the same reference characters in all figures.

The schematically illustrated electronic circuit breaker 1 comprises a power transistor or semiconductor switch 2 in the form of a MOSFET, downstream of which a current sensor 4 is connected in a current path 3, namely, the positive path of circuit breaker 1. Current path 3 extends between an operating voltage connection or voltage input 5 and a positive load connection 6. The positive pole of a load L to be switched is connected to said load connection, whereas the negative pole of the load is to be connected to a corresponding negative load connection 7 of circuit breaker 1. Said connection 7 in the exemplary embodiment is taken to ground GND. The operating or input voltage V_E generated by a current or voltage source of a power supply unit 8 in the form of, for example, a direct voltage with 24 V (DC) is applied at voltage input 5 of electronic circuit breaker 1.

In the case of connected voltage source 8 and connected load L, during operation of circuit breaker 1 a load current I_L drains to a reference potential or to ground GND proceeding from voltage input 5 over current path 3 and therefore over the drain-source

path of semiconductor switch 2 and across load L. This load current I_L flowing across semiconductor switch 2 and load L is detected by current sensor 4. The detected current I_L , which because of the series connection of semiconductor switch 2 and load L corresponds to the drain-source current I_{ds} flowing across semiconductor switch 2, is routed as current signal S_I to a first input E_I of a control unit 9.

Based on this current measurement, the semiconductor switch can be triggered within the scope of a constant current limitation by the control unit such that in the event of an overload or short circuit load, current I_L is limited at least briefly to a predetermined maximum current value. This is, for example, 1.1 times the rated current I_N in the event of an overload. In the event of a short circuit, this maximum current value can be, for example, twice the rated current I_N . When there is only one threshold value for the case of the overload and short circuit, the maximum current value can be, for example, 1.5 times the rated current I_N .

A first voltage signal S_{Vd} is supplied in addition to control unit 9 via a second input E_{Vd} . This voltage, detected by a first voltage sensor 10, in the exemplary embodiment corresponds both to the input or operating voltage V_E and to the drain voltage V_d of semiconductor switch 2 at its drain connection D.

A second voltage signal S_{Vs} is supplied in addition to control unit 9. In the exemplary embodiment, this refers to both the source voltage V_s at source connection S of semiconductor switch 2 and to load voltage V_L . Voltage signal V_s , detected in turn by a corresponding second voltage sensor 11, is routed to a third input E_{Vs} of control unit 9.

From the detected voltage values V_d and V_s and from the detected drain-source current I_{ds} , which corresponds to load current I_L detected by current sensor 4, control unit 9 determines the current power P_{FET} of semiconductor switch 2 according to the relation $P_{FET} = (V_d - V_s) \cdot I_{ds}$ and adjusts it by dynamic current limitation of the load and semiconductor current $I_L (= I_{ds})$ by the appropriate limitation of said current I_{ds} in such a way that the power P_{FET} does not exceed a specific, maximum power value P_{max} . This

power value is, for example, $P_{\max} = 50 \text{ W}$, which is achieved if necessary by the appropriate dynamic triggering of semiconductor switch 2 but is not exceeded. To this end, control unit 9 generates an appropriate control signal S_G , which can be tapped at an output A_G of control unit 9 and is routed to gate connection G of semiconductor switch 2.

A relatively low-power semiconductor switch 2 can be used, based on this dynamic current limitation, current control, or current regulation of semiconductor switch 2 by control unit 9, by detecting and evaluating drain-source voltage V_{ds} of semiconductor switch 2 and the current I_{ds} flowing across it and as a result of the corresponding power limitation of semiconductor switch 2 to a power value P_{FET} that is less than or equal to $P_{\max}$.

Whereas in the prior art to implement a 10 A circuit breaker ($I_N = 10 \text{ A}$) with a normal power dissipation of less than 5 W, it would have to be equipped with a 300 W MOSFET due to the switch-on effects in the case of capacitive loads, a substantially smaller dimensioned MOSFET can be used as semiconductor switch 2 by means of the power control of the invention by dynamic current limitation.

FIG. 2 in a current/voltage-time diagram shows the profile of load current I_L and load voltage V_L as a result of the power control of semiconductor switch 2 during a switch-on process of a capacitive load L as a result of the correspondingly adjusted gate signal S_G of semiconductor switch 2 in the case of a stepped or step-shaped increase in load current I_L . FIG. 3 shows the situation in the case of a ramp-shaped increase in current.

The invention is not limited to the exemplary embodiments described above. Rather, other variants of the invention can also be derived herefrom by the skilled artisan, without going beyond the subject of the invention. Particularly, further all individual features described in relation to the exemplary embodiments can also be combined with one another in a different manner, without going beyond the subject of the invention.

List of Reference Characters

1	Electronic circuit breaker
2	Semiconductor switch
3	Current path/positive path
4	Current sensor
5	Voltage input
6	Load connection (positive)
7	Load connection (negative, ground)
8	Voltage source/power supply unit
9	Control unit
10	First voltage sensor
11	Second voltage sensor
A_G	Output
D	Drain/connection
E_I	First input
E_{Vd}	Second input
E_{Vs}	Third input
G	Gate/connection
GND	Ground/reference potential
L	Load
S	Source/connection
S_I	Current signal
S_{Vd}	First voltage signal
S_{Vs}	Second voltage signal
S_G	Gate signal
I_{ds}	Semiconductor/drain-source current
I_L	Load current
I_N	Rated current
V_E	Operating/input voltage

V_d	Drain voltage
V_s	Source voltage
V_{ds}	Drain-source voltage
P_{FET}	Semiconductor power
P_{max}	Power value/maximum power

Claims

1. An electronic circuit breaker (1) with a semiconductor switch (2), the drain connection (D) and source connection (S) of which are connected between a voltage input (5) and a load output (6), and the gate connection (G) of which is connected to a control unit (8), to which at the input end a signal (S_i), representing the load current (I_L , I_{ds}), is supplied,
characterized in that
the control unit (8) determines the drain-source voltage (V_{ds}) and from this and from the detected load current (I_L , I_{ds}) routes a control signal (S_G), adjusting the power (P_{FET}) of the semiconductor switch (2) to less than or equal to a maximum power value (P_{max}), to the gate connection (G) of the semiconductor switch (2).
2. The electronic circuit breaker (1) according to claim 1,
characterized in that
the control unit (9) is supplied with a voltage signal (S_{Vd} , S_{Vs}) representing the drain voltage (V_d) and representing the source voltage (V_s) of the semiconductor switch (2).
3. The electronic circuit breaker (1) according to claim 1 or 2,
characterized in that
the control unit (9) at the input end is connected to a voltmeter (10) detecting the input voltage (V_E) and/or the drain voltage (V_d) of the semiconductor switch (2) and to a voltmeter (11) detecting the load voltage (V_L) and/or the source voltage (V_s) of the semiconductor switch (2).
4. The electronic circuit breaker (1) according to claim 2 or 3,
characterized in that
the control unit (9) determines the drain-source voltage (V_{ds}) of the semiconductor switch (2) from the difference of the detected drain or input voltage (V_d , V_E) and the detected source or load voltage (V_s , V_L).

5. The electronic circuit breaker (1) according to one of claims 1 to 4,
characterized in that
the control unit (9) depending on the detected load current (I_L) triggers the semiconductor switch (2) in such a way that in the event of overload and/or a short circuit the load current (I_L) is limited to a threshold value (I_{max}).
6. The electronic circuit breaker (1) according to one of claims 1 to 4,
characterized in that
the semiconductor switch (2) is a field-effect transistor, in particular, a MOSFET, the drain connection (D) of which is associated with the voltage input (5) and source connection (S) of which is associated with the load output or connection (6).
7. A method for operating an electronic circuit breaker (1) and/or for triggering a semiconductor switch (2) of such a circuit breaker (1), with a semiconductor switch (2) connected between a voltage input (5) and a load output (6), and to which on the triggering side a control signal (S_G) is supplied derived from the load current (I_L , I_{ds}) and from the drain-source voltage (V_{ds}), by means of which the power (P_{FET}) of the semiconductor switch (2) is adjusted to less than or equal to a maximum power value (P_{max}).
8. The method according to claim 7, wherein the power (P_{FET}) of the semiconductor switch (2) at least during the switch-on process of a load (L) is adjusted to less than or equal to the maximum power value (P_{max}).
9. The method according to claim 7 or 8, wherein the drain-source voltage (V_{ds}) of the semiconductor switch (2) is determined from the drain or input voltage (V_d , V_E) and from the source or load voltage (V_s , V_L).

10. The method according to one of claims 7 to 9, wherein the semiconductor switch (2) is triggered in such a way that in the event of an overload and/or short circuit, the load current (I_L) is limited to a threshold value (I_{max}).