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**Title: "A SYSTEM AND A METHOD FOR PROTECTING AN ELECTRIC MOTOR AND ITS
CONTROL CIRCUIT, AND AN ELECTRIC MOTOR"**

The present invention refers to a system and method for protecting a combina-
5 tion of an electric motor and its control circuit, which aims at detecting possible technical
failures that cause the current to rise.

An electric motor basically comprises a rotor and a stator. In order for this motor
to function, that is so say, for the rotor to start moving, voltage is applied to the stator, in-
ducing the movement of the rotor.

10 Usually, the control of rotation speed of the motor is carried out by means of
inverters, which in turn are formed from switches, as for instance a MOSFET (transistor).

The application of electric motors having controlled speed is widespread, being
used, for instance, for driving compressors, household appliances, traction, etc.

15 Basically, when used in permanent-magnet motors without position sensors,
the inverters are constituted by a set of diodes for branching the alternate voltage, from a
control central that actuates the switches and a block responsible for detecting the position
of the rotor by monitoring the voltages in the phases of motor, making a comparison be-
tween the monitored values. The control of the motor is carried out by modulating the volt-
age on the phase of the motor, which consists in applying and interrupting the voltage on the
20 phases at a high frequency. By means of this modulation, it is possible to control the current
supplied to said phases of the motor, and one can adjust it at the desired torque and speed
for its operation.

In the case of induction motors, the position detector of the rotor is not used, the control of speed and torque being effected by modulating the voltage on the phases of the motor.

5 In both cases, a control central is employed, which is usually constituted by a microcontroller or a signal processor, which receives the external command for operation of the motor and starting from the monitoring of internal variables of the motor/inverter (current on the motor, position of the rotor, etc.), generating commands that supply voltage and current to the motor.

10 During the actuation and functioning of the motor, the current may undergo rises (or surge current) as a result of a overload or else as a result of a short-circuit.

The rise of the current resulting from a overload does not immediately endanger the integrity of the motor and can be controlled. However, the current rise resulting from a short-circuit has a very rapid action, and so a protection mechanism should be actuated in order to prevent damage to the motor or the respective control circuit.

15 **Description Of The Prior Art**

The systems and methods for detecting surge current in electric motors known from the prior art usually actuate by using a predetermined current value, that is to say, a maximum current value is predetermined, so that the motor will not be damaged and, once this value is exceeded, a protection mechanism is actuated, protecting the motor or the
20 respective control circuit. However, this protection method does not enable one to differentiate whether the current rise results from a overload or from a short-circuit, causing the protection mechanism to be actuated in either situations.

One prior art approach is disclosed in GB 2 267 190 and is related to a circuit breaker to shut down the power of an electric motor in the event of a failure. According this
25 solution, three separate circuits detect a slight-overload, a severe-overload or a short-circuit, these circuits being connected to a led panel to indicate the type of problem that accrued.

Another related prior art is disclosed in US 4 558 264. According this document, an electric motor is controlled by measuring the electric current being applied. It is not foreseen a solution to protect the motor in case of a overload or short-circuit.

Short Description Of The Invention

The objective of the present invention is to provide a system and a method for detecting the occurrence of surge on electric motors and its control circuit, which will enable one to distinguish the occurrence of overload on the motor from a short-circuit, by using only a current detector adjusted to a preferred limit.

This objective is achieved by means of a protection system including a control circuit of an electric motor for protecting the control circuit and the electric motor, the control circuit comprising a set of switches to control the speed of the motor, the system comprising a control central connected to the control circuit, the central control selectively commanding the switches, the central control measuring an electricity conduction time of each of the switches and measuring a disturbance time passed between the beginning of the conduction of one of the switches and the occurrence of a surge current, the surge being measured by means of a surge detector which compares the value of a current that flows through the control circuit to a predetermined current value, the central making a comparison between the disturbance time and the conduction time to determine whether the surge current results from an overload or from a short-circuit on the electric motor or any of the switches.

The present invention also refers to a method for protecting an electric motor and its control circuit, the speed control of the motor being carried out by selectively commanding a set of switches, the method comprising the steps of: measuring an electricity conduction time of each of the switches, measuring the disturbance time passed between the beginning of conduction of one of the switches and the occurrence of a surge, the occurrence of the surge being measured by means of the comparison of the value of a current that flows through the control circuit to a predetermined current value, comparing the disturbance time with the conduction time, to determine whether the surge current results from an overload or from a short-circuit of the electric motor or on any of the switches.

In addition, the present invention refers to an electric motor having phases, said phases being fed by a set of switches, said switches being controlled by a control circuit to modulate a voltage that is applied to said phases to control the speed of the motor, the control of the switches being carried out by a control central connected to the control circuit, the control central measuring the electricity conduction time of each of the switches and measuring the disturbance time passed between the beginning of conduction of one of the switches and the occurrence of a surge current, the surge being a value of a current that flows through the phases higher than a predetermined current value, the control central mak-

ing a comparison between the disturbance time and the conduction time to determine whether the surge current results from an overload or from a short-circuit of the phases of the electric motor or any of the switches.

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Brief Description Of The Drawings

The present invention will now be described in greater detail with reference to an embodiment represented in the drawings, in which:

10 - Figure 1 represents a schematic diagram of the speed control circuit of the motor and of the surge current detector according to the present invention;

- Figure 2 shows a temporal diagram representing the behavior of the current in a overload current situation;

- Figure 3 shows a temporal diagram representing the behavior of the current in a short-circuit situation;

15 - Figure 4 represents a flow-diagram of the method according to the present invention.

Detailed Description Of The Figures

20 The system for protecting an electric motor and its control circuit according to the present invention basically comprises a surge current detector 3, adjusted to a determined current limit.

Figure 1 schematically illustrates the motor 1 and the respective circuits for its control 2 and feeding. According to a preferred embodiment of the present invention, the motor 1 described will be of the three-phase type, which does not prevent the invention from being applied to another type of electric motor.

25 As can be seen from figure 1, the motor 1 and its control circuit 2 are fed by a source supplying alternate voltage that will be rectified by a set of diodes D and filtered by a capacitor C₁. A set of switches Ch1 - Ch6 is responsible for the modulation of the voltage on the phases F₁, F₂, and F₃ of the motor 1. The control of the set of switches Ch1 - Ch6 is carried out by a control central 7.

The detection of surge current is carried out by means of a surge-current detecting circuit 3 that is connected to the control central 7, which measures the current I_{RS} that flows along the circuit through the resistor R_s , that is to say, the current that flows through the switches Ch1-Ch6.

5 As illustrated in figure 1, the resistor R_s is installed in a position of the circuit that allows one to read the current I_M flowing through phases F_1 , F_2 , and F_3 of the motor, the current I_{RS} basically representing the current I_M .

The control central 7 emits commands for closing and opening the switches Ch1 - Ch6, besides receiving external information, such as the signal D_s , for instance. The
10 signal D_s is generated by the surge current detector 3, when a predetermined I_{LIMIT} value (current limit) is exceeded.

The surge current detector 3 comprises an operational amplifier mounted as a voltage comparator C_o , the inlets of which are fed with voltages "E-" and "E+", wherein "E+" is the voltage of the first terminal of the resistor R_s , and "E-" is the voltage of the other
15 terminal of this resistor R_s , plus an essentially constant voltage, defined by the voltage divider R_A and R_B . The $+V_B$ voltage is a constant.

The resistor R_1 causes the voltage variations on the resistor R_2 (represented by the current I_M of the motor) to be added to the constant voltage defined by the resistors R_A and R_B .

20 For a situation in which the current I_M flowing through the motor 1 is close to zero, the voltage "E-" is higher than the voltage "E+", thus causing the outlet D_s of the voltage comparator C_o to be at "low" level.

When the current through the motor 1 rises above a I_{LIMIT} limit defined by the resistors R_A , R_B and R_1 , the voltage in the inlet "E-" becomes lower than the voltage in the
25 inlet corresponding to a current value beyond the admissible limit, that is to say, above the I_{LIMIT} limit, thus characterizing the detection of surge current. In this situation, the outlet of the comparator C_o passes from "low" level to "high" level, signaling the occurrence of surge current to the control central 7 by means of D_s .

The differentiation between a overload and a short-circuit is made by measuring the rise variation time of the current I_{RS} , i.e., in the event of overload, the current rise
30 occurs gradually, taking a relatively long period of time, until the I_{LIMIT} value is reached,

whereas in the cases when the motor 1 enters into short-circuit, the I_{LIMIT} value is reached much more rapidly, thus enabling one to detect this kind of failure by measuring the time.

As already known from the prior art, the speed control is carried out by means of switches Ch1 - Ch6 and, as illustrated in figures 2 and 3, the switches Ch1, Ch4 conduct
5 electricity for a determined period of time T_c (conduction time) that varies depending upon the rotation speed to be imposed to the motor 1.

In order to determine by means of the control central 7 whether the kind of failure on the motor 1 results from a overload or from a short-circuit, the present invention foresees the T_c -time and T_d -time (disturbance time) measurement. The T_d -time is counted
10 from the beginning of the conduction of the switches Ch until the moment when the current has reached the I_{LIMIT} value, that is to say, when the surge current occurred (see figures 2 and 3). The T_c -time is the time of conduction of the switches Ch and depends upon the situation of motor operation (basically speed and load).

Figures 2 and 3 represent the temporal diagrams of the situations of overload
15 and short-circuit, respectively. By comparing the two diagrams, one can see in detail that, in the short-circuit situation, the current I_{RS} reaches the I_{LIMIT} value in much shorter T_d time when compared with the T_d time in the overload situation.

As can be seen from figure 4 schematically, the criterion used for determining whether the surge current results from an overload or from a short-circuit depends upon a
20 relation between the T_d and T_c times. Thus, when the relation $T_d < T_c \cdot k$ is true, this means that the motor 1 is in short-circuit, and when the relation is false, this means that the motor 1 has undergone a overload. The measurement of the T_d and T_c times, as well as the comparison between the respective values is carried out by means of the control central 7.

The value of the constant k is a fraction or portion of the T_c value (being a
25 number between 0 and 1), and defines the limit for the distinction of the kind of failure that occurred on the motor 1, and may vary depending upon the type of motor 1 in use, in addition to the protection level to be given to the latter.

For instance, if the value of k is 50% (or 0.5) and if the T_d time is short (shorter
30 than 50% of T_c), this means that the motor 1 is in short-circuit, and it is necessary to add some protection mechanism in order to avoid damage to said motor 1. In the cases when T_d is longer (longer than or equal to 50% of T_c), this means that the motor 1 has undergone a overload.

Besides enabling one to differentiate the kind of failure occurred on the motor 1 or on one of the switches Ch1 - Ch6, the present invention further enables one to estimate the value of the surge that occurred on the motor 1 by evaluating the proportion T_d/T_c .

5 A preferred embodiment of the invention having been described, it should be understood that the scope of the present invention embraces other possible variations, being limited only by the contents of the accompanying claims, the possible equivalents being included therein.

Claims

1. A protection system including a control circuit (2) of an electric motor (1) for protecting the control circuit (2) and the electric motor (1),

the control circuit (2) comprising a set of switches (Ch) to control the speed of
5 the motor (1),

the system being characterized by:

comprising a control central (7) connected to the control circuit (2), the central control (7) selectively commanding the switches (Ch),

the central control (7) measuring an electricity conduction time (T_c) of each of the
10 switches (Ch) and measuring a disturbance time (T_d) passed between the beginning of the conduction of one of the switches (Ch) and the occurrence of a surge current, the surge being measured by means of a surge detector (3) which compares the value of a current (I_{RS}) that flows through the control circuit (2) to a predetermined current (I_{LIMIT}) value,

the central (7) making a comparison between the disturbance time (T_d) and the
15 conduction time (T_c) to determine whether the surge current results from an overload or from a short-circuit on the electric motor (1) or any of the switches (Ch).

2. A protection system according to claim 1, characterized in that the control central (7) indicates a condition of short-circuit of the motor (1) or on one of the switches
20 (Ch) when the disturbance time (T_d) is shorter than the conduction time (T_c) multiplied by a factor (k) that ranges from 0 to 1, the central control (7) indicating a condition of overload of the motor (1) when the disturbance time (T_d) is longer than the conduction time (T_c) multiplied by said factor (k).

25 3. A protection system according to claim 2, characterized in that said factor (k) is equal to 0.5.

4. A method for protecting an electric motor (1) and its control circuit (2),
the speed control of the motor (1) being carried out by selectively commanding a
30 set of switches (Ch),

the method being characterized by comprising the steps of:

measuring an electricity conduction time (T_c) of each of the switches (Ch),

measuring the disturbance time (T_d) passed between the beginning of conduction of one of the switches (Ch) and the occurrence of a surge, the occurrence of the surge being

measured by means of the comparison of the value of a current (I_{RS}) that flows through the control circuit (2) to a predetermined current (I_{LIMIT}) value,

comparing the disturbance time (T_d) with the conduction time (T_c), to determine whether the surge current results from an overload or from a short-circuit of the electric mo-

5 tor (1) or on any of the switches (Ch).

5. A method according to claim 4, characterized in that, in said comparison step, a condition of short-circuit of the motor (1) or on one of the switches (Ch) is indicated when the disturbance time (T_d) is shorter than the conduction time (T_c) multiplied by a factor (k)
10 that ranges from 0 to 1, and an overload condition of the motor (1) is indicated when the disturbance time (T_d) is longer than the conduction time (T_c) multiplied by said factor (k).

6. A method according to claim 6, characterized in that, in said comparison step said factor (k) is equal to 0.5.
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7. An electric motor (1) having phases (F),
said phases (F) being fed by a set of switches (Ch),
said switches (Ch) being controlled by a control circuit (2) to modulate a voltage that is applied to said phases (F) to control the speed of the motor (1),
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the motor (1) being characterized in that the control of the switches (Ch) is carried out by a control central (7) connected to the control circuit (2),

the control central (7) measuring the electricity conduction time (T_c) of each of the switches (Ch) and measuring the disturbance time (T_d) passed between the beginning of conduction of one of the switches (Ch) and the occurrence of a surge current,
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the surge being a value of a current (I_{RS}) that flows through the phases (F) higher than a predetermined current (I_{LIMIT}) value,

the control central (7) making a comparison between the disturbance time (T_d) and the conduction time (T_c) to determine whether the surge current results from an overload or from a short-circuit of the phases (F) of the electric motor (1) or any of the switches (Ch).
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8. A motor according to claim 7, characterized in that the control central (7) indicates a condition of short-circuit of the motor (1) when the disturbance time (T_d) is shorter than the conduction time (T_c) multiplied by a factor (k) that varies between 0 and 1, the central (7) indicating a condition of overload of the motor (1) when the disturbance time (T_d) is
35 longer than the conduction time (T_c) multiplied by said factor (k).

9. A motor according to claim 8, characterized in that said factor (k) is equal to 0.5.