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(54) ELECTRICAL SHORT-CIRCUIT MONITORING ARRANGEMENT
Convention Application for a Patent

We, SIEMENS AKTIENGESELLSCHAFT

of Wittelsbacherplatz 2, D-8000
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hereby apply for the grant of a Patent for an invention entitled

"AN ELECTRICAL SHORT-CIRCUIT-MONITORING ARRANGEMENT FOR A SPEED-REGULATED ROTARY CURRENT MOTOR INCLUDING ITS SUPPLY LINES"

which is described in the accompanying complete specification.

This application is a Convention Application and is based on the application numbered P 34 42 827.5

for a patent or similar protection made in Federal Republic of Germany

on 23 November 1984

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Dated this 18th day of July 1985

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PATENTS ACT 1952
An Electrical Short-Circuit Monitoring Arrangement for a Speed-Regulated Rotary Current Motor Including its Supply Lines
According to Fig.1, a short-circuit monitoring arrangement 10 comprises a phase motor unit 11 with one phase monitoring element 12,13,14 for monitoring each of the motor phases U-V, V-W and U-W, respectively. The arrangement 10 also comprises a clearing module 15 and a switching module 16. Each of the phase monitoring elements 12,13,14 is allocated a relay switch d1,d1',d1", which are connected in series and coupled to the switching module 16. As long as the contacts of all the relay switches d1,d1' and d1" are closed, the isolating switch 5 does not react, so that its contacts are also closed. Should one of the relay switch contacts open, for instance because of a short-circuit in one of the motor phases in a manner still to be described, the exciting current circuit of the isolating switch 5 is likewise interrupted by the switching module 16. The isolating switch 5 therefore opens its contacts and isolates the frequency converter/motor unit from the supply grid RST. The current supply to the monitoring arrangement 10 is provided via the supply element 17.
Claim

1. An electrical short-circuit monitoring arrangement for a rotary current motor, including its supply lines, which motor is speed-regulated by means of an intermediate-circuit current frequency converter comprising a supply-driven thyristor power rectifier on the supply side, an intermediate circuit choke, and a self-commutated power inverter on the machine side, wherein harmonic voltage produced by the intermediate-circuit current frequency converter as a result of the commutation, which harmonic voltage is superimposed on the motor voltage, is detected at the output of the converter, filtered and supplied to a phase monitoring unit which, if a selectable amplitude value of the harmonic voltage of at least one phase is not reached, activates a switching module comprising a switch which, when a cut-out signal occurs, operates an isolating switch for interrupting the motor current supply circuit.
"AN ELECTRICAL SHORT-CIRCUIT MONITORING ARRANGEMENT FOR A SPEED-REGULATED ROTARY CURRENT MOTOR INCLUDING ITS SUPPLY LINES"

The following statement is a full description of this invention, including the best method of performing it known to us.
An Electrical Short-Circuit Monitoring Arrangement for a Speed-Regulated Rotary Current Motor including its Supply Lines

The invention relates to an electrical short-circuit monitoring arrangement for a speed-regulated rotary current motor including its supply lines.

An electrical short-circuit monitoring arrangement of the type mentioned has substantial significance in the field of underground mining. Because of the threat of overheating and, with it, of explosion in the fire-damp, owing to short circuits, it is necessary underground not just to monitor the motor itself, for instance with the help of a motor protection circuit, but also its supply lines in the region at risk from explosion. The monitoring itself should take place outside this region, because otherwise the monitoring arrangement itself would also have to be designed to be protected against explosion. In fact, an even greater significance attaches to the monitoring of the motor supply lines than to the monitoring of the motor itself, because the latter normally possesses a thermal overload protective safety device.

In underground mining there exists therefore the requirement that a motor supply line, in which a short circuit current occurs, must be isolated from the supply itself within 100 ms. With intermediate-circuit current frequency converters this is normally achieved by means of a monitoring device for the magnetic flux of the connected motor, which monitoring device is built into the motor control or regulating circuitry. Such a monitoring device may not however function until frequencies exceed 5 to 7 Hz. This corresponds to a motor speed of about 10% of the rated speed with a 50 Hz supply. In the range between 0 and 10% the line between
converter and motor, and also the motor itself, remain unmonitored for short circuits. The use of a current measuring device to detect such short circuits is out of the question since, as a result of the current limiting circuit always present in the control or regulating circuit of the converter, it cannot be distinguished whether excess current is brought about by overload or by short circuit.

According to the present invention there is provided an electrical short-circuit monitoring arrangement for a rotary current motor, including its supply lines, which motor is speed-regulated by means of an intermediate-circuit current frequency converter comprising a supply-driven thyristor power rectifier on the supply side, an intermediate circuit choke, and a self-commutated power inverter on the machine side, wherein harmonic voltage produced by the intermediate-circuit current frequency converter as a result of the commutation, which harmonic voltage is superimposed on the motor voltage, is detected at the output of the converter, filtered and supplied to a phase monitoring unit which, if a selectable amplitude value of the harmonic voltage of at least one phase is not reached, activates a switching module comprising a switch which, when a cut-out signal occurs, operates an isolating switch for interrupting the motor current supply circuit.

An embodiment of the invention may provide short circuit monitoring also in the range below 10% of rated motor speed.

An embodiment of the invention enables a short circuit on the motor side of an intermediate-circuit current frequency converter, particularly in the range up to 15 Hz, to be detected by technical measurement and used as a control value or criterion. In order to determine occurrence of a short circuit, one employs the
current ripple of the intermediate circuit current, occurring in the case of the B6-circuit of the carrier power converter with six times the supply frequency. This current ripple gives rise to a corresponding harmonic voltage. This harmonic voltage arises at the leakage reactance of the motor and intermediate circuit of the converter, and falls to zero in the case of short circuit. Since this may arise in all three phases it can, moreover, be determined in which phase the short circuit has occurred.

For a better understanding of the invention and to show how it may be put into effect, reference will now be made, by way of example, to the accompanying drawings in which:

Fig.1 is a block circuit diagram of a motor current supply circuit with an intermediate-circuit current frequency converter, as well as a short-circuit monitoring arrangement and switching equipment within the motor current supply circuit; and

Fig.2 is a basic circuit diagram of the monitoring arrangement with a phase monitoring unit, clearing module and switching module.

According to Fig.1 a rotary field current motor 1 is coupled via supply or feed lines U,V,W, to the output of an intermediate-circuit frequency converter. This consists of a self-commutated power inverter 2 on the machine side, an intermediate-circuit choke 3, and a mains-driven thyristor power rectifier 4 on the grid or supply side in B6-connection. The rectifier’s input terminals are coupled, via an isolating switch 5, safety devices 6 and a master switch 7, to the three phase supply network RST.

Speed regulation of the motor 1 takes place in a known manner, by means of a value set at a desired value selector \( R_n \) with the help of a regulating arrangement.
8. This detects the input current value measured by a current transformer 9, the output current value measured by a current transformer 10, and the value formed from these values and the output voltage of the magnetic exciting flux. By means of these values the thyristors of the supply-side rectifier 4 and of the machine-side inverter 2 are influenced by the regulating arrangement 8, by phase control of the power rectifier 4 on the supply side, and by commutation control of the power inverter 2 on the machine side, so that a desired speed is attained.

The electronic commutation, as it is described for example in the book "Netzgeführte Stromrichter" by Mülken, 1983 under 2, pages 15 and the following pages, causes a current ripple. This brings about a corresponding harmonic voltage at the leakage reactance of the motor which, with the illustrated rectifier circuit and a supply frequency of 50 Hz, reaches a frequency of 300 Hz. This harmonic voltage occurs in all three phases of the motor current supply circuit.

When the harmonic voltage occurs on the output side at the leakage reactance of the motor, it breaks down on the occurrence of a short circuit within the motor feed lines or within the motor coil.

The underlying idea of the invention is to make this characteristic feature of the harmonic voltage useable for short circuit monitoring, with the help of the arrangement described in the following.

According to Fig.1, a short-circuit monitoring arrangement 10 comprises a phase motoring unit 11 with one phase monitoring element 12, 13, 14 for monitoring each of the motor phases U-V, V-W and U-W, respectively. The arrangement 10 also comprises a clearing module 15 and a switching module 16. Each of the phase monitoring elements 12, 13, 14 is allocated a relay switch d1, d1', d1''.
which are connected in series and coupled to the switching module 16. As long as the contacts of all the relay switches d1,d1' and d1" are closed, the isolating switch 5 does not react, so that its contacts are also closed. Should one of the relay switch contacts open, for instance because of a short-circuit in one of the motor phases in a manner still to be described, the exciting current circuit of the isolating switch 5 is likewise interrupted by the switching module 16. The isolating switch 5 therefore opens its contacts and isolates the frequency converter/motor unit from the supply grid RST. The current supply to the monitoring arrangement 10 is provided via the supply element 17.

Fig. 2 shows the basic circuit diagram of the phase monitoring unit 12, the clearing module 15 and the switching module 16, the monitoring arrangement functioning as follows.

Each of the phase monitoring elements 12,13,14 comprises a respective adjustment and decoupling stage 18,19,20, to each of which is allocated one evaluating electronics circuit 21,22,23 respectively. Since the phase monitoring elements of all three channels are constructed identically, only the basic circuit diagram of the phase monitoring element with the adjustment and decoupling stage 18, allocated to the phase channel U-V, as well as its evaluating electronics circuit 21, is shown and described.

After the arrangement has been switched-on by operating the master switch 7, first of all the phase voltage (U-V; V-W and U-W) is applied to the associated high-pass filter 24, which filters-out the harmonic voltage and supplies it to an opto-coupler 25. The measurement signal obtained in this manner, which is proportional to the harmonic voltage and is electrically isolated from the power circuitry, is supplied to the
evaluating electronics 21. It is supplied via a pulse shaper stage 26 to a transformer 27 which, with the help of a rectifier 28 and a smoothing RC circuit 29, 30 converts the incoming signal into a control direct current and supplies it to the base resistor 31 of a monitoring switching transistor 32.

In the collector-emitter circuit of the transistor 32 lie a channel relay D1 and an emitter resistor 33 of a clearing-switching transistor 34. The base of this transistor 34 is coupled to the clearing module 15. The latter contains a switching transistor 35 whose base is connected, via an adjustable resistor 36, and an adjustment element 37, to the current transformer 9 (Fig.1).

When the arrangement is set in operation by operating the master switch 7, voltage is applied to the input terminals 38, 39 of the switching module 16 via the supply element 17. The phase monitoring unit 11 (Fig.1) simultaneously receives positive voltage, via the closed contact d3 of a not-yet-excited cut-off relay D3 (which is provided as a magnetic latching relay with mechanical resetting) as well as via a change-over contact d4 located in the shown position, and via output terminal 40 of the switching module 16.

The negative voltage is applied via the terminal 39 of the switching module 16 via the relay D2, the central pole of its change-over contact d2, and a series resistance 41 of the relay D4. This resistance and a further resistance 42 wired to it in series, are dimensioned in such a way that this relay cannot attract first of all. Corresponding to the motor current measured by the current transformer 9, a control variable produced by the adjustment stage 37 is applied to the terminal 43 and, via the adjustable resistance 36, to the base of the switching transistor 35. Before a definite
bias voltage is reached at the base resistance 44, the switching transistor 35 is blocked. Thereby the base of the clearing-switching transistor 34 becomes positive, so that this transistor conducts and the relay D₁ attracts.

As soon as the motor current crosses a definite threshold value, which can be set at the resistance 36, the switching transistor 35 becomes conductive so that the voltage at the base of the clearing-switching transistor 34 sinks so far that the relay D₁ would fall-off if, through the occurrence meanwhile of the harmonic voltage, the transistors 32,34 were not simultaneously driven by this voltage. With that the circuit is "sharpened" or rendered responsive. The sharpening or response point is so chosen also that it can always be reached through the magnetising current of the motor in no-load or idling operation.

Through the application of the voltage the relay D₂ has also attracted, and a capacitor 45 lying parallel to it is charged. Thus, the relay is prevented from falling-off in the event of short-term current interruptions through change-over operations of the change-over contact d₄.

By attraction of the relay D₂, its change-over contact d₂ switches from the shown position into the opposite position, and thus short circuits the resistance 41, so that from now on the relay D₄ also can attract and close its contact d₄. The cut-off relay D₃ remains, however, isolated through the diode 47, from the voltage supply.

By the attraction of the relay D₄, certainly its change-over contact d₄ also changes-over from the shown into the opposite position, so that the cut-off relay D₃ is prepared from now on for cut-off. Because of the by-now closed normally-open contact d₄ and the still-closed normally-closed contact d₃, the isolating
switch 5 can be switched-on via the terminals 45,46 of the switching module 16. Also, the supply voltage is applied to the intermediate-circuit current converter 2,3,4,8, so that the motor 1 is set in motion.

By means of the contact $d_4$, it is achieved that, with supply voltage at the terminals 38,39 not or no longer present, the motor 1 cannot be switched-on or is switched-off. Once the motor current supply circuit is in operation, the harmonic voltage of all three phases is applied to the corresponding inputs of the adjustment and decoupling stages 18,19,20, which form therefrom a driving voltage which falls-off, via the pulse former stage 26 and the transformer 27 with rectifier 28, as direct voltage, at the resistance 31 and therewith occurs at the base of the switching transistor 32, so that the latter and the transistor 34 become conductive, the relay $D_1$ excites and its contact $d_1$ remains closed.

Because of the similar function of all the monitoring elements, the occurrence of the harmonic voltage in the relevant phases is therewith presupposed, also the contacts $d_{1'}$ and $d_{1''}$ are closed. Therewith all phase monitoring elements are still connected, also after operation of the change-over contact $d_4$, to voltage via the closed contacts $d_1$, $d_{1'}$ and $d_{1''}$.

The monitoring arrangement has thereby reached a steady state, which characterises the normal case. If a phase short circuit now occurs in the motor current supply circuit, then the harmonic voltage breaks down in the relevant phase. This has the result that the base voltage of the switching transistor 32 becomes zero and blocks the latter. Therewith the relay $D_1$ falls-off and opens its associated contact $d_1$. Thus the voltage at the terminal 40 of the circuit module breaks down, so that the relay $D_2$ falls-off. Thus, its change-over contact $d_2$ gets into the shown position again, so that the cut-off
relay $D_3$ is excited. The value of the resistance $41$ is chosen so that the relay $D_4$ remains attracted, despite the clearing of this resistance, through $d_4$. Through opening the contact $d_3$ the exciting circuit of the isolating switch 5, connected to the terminals 45, 46 of the switching module 16, is broken and interrupts the primary motor current circuit.

Since the cut-off relay $D_3$ possesses a mechanical resetting device, the arrangement cannot be brought into operation again until this resetting is effected by hand. Thus it is not possible to switch the motor back-on until the disturbance has been "acknowledged" by an operator on the spot.

Because of the series connection of the contacts $d_1$, $d_1'$ and $d_1''$, cut-off follows regardless of whether the short circuit occurs in only one, two or in all phases.

Because operational readiness is provided only with the attracted relay $D_1$, the whole of the circuit except for the switching transistors 32 and 34 is self-monitoring. That is, if some disturbance or other occurs except to these transistors, an interruption of the motor current circuit follows. A further advantage is that when a disturbance occurs and one of the contacts $d_1$ opens as a result, with operation of the cut-off relay $D_3$, through the latter's self-opening normally-closed contact $d_3$, the supply voltage is simultaneously cut-off from the monitoring device. Through this isolating of the monitoring arrangement from the supply in the case of a disturbance, reactions produced by undefined oscillatory processes of the output voltage of the converter, such as can occur in the moment of cut-off, are made ineffective. A further advantage is that the arrangement is not made sharp or responsive through the clearing module until a certain minimum current flows.
This is of significance because the harmonic voltage is only present with a minimum current value of the motor current. If this minimum current is not reached, the arrangement is automatically blocked. Thereby a maximum of security against erroneous cut-off is guaranteed.
The claims defining the invention are as follows:

1. An electrical short-circuit monitoring arrangement for a rotary current motor, including its supply lines, which motor is speed-regulated by means of an intermediate-circuit current frequency converter comprising a supply-driven thyristor power rectifier on the supply side, an intermediate circuit choke, and a self-commutated power inverter on the machine side, wherein harmonic voltage produced by the intermediate-circuit current frequency converter as a result of the commutation, which harmonic voltage is superimposed on the motor voltage, is detected at the output of the converter, filtered and supplied to a phase monitoring unit which, if a selectable amplitude value of the harmonic voltage of at least one phase is not reached, activates a switching module comprising a switch which, when a cut-out signal occurs, operates an isolating switch for interrupting the motor current supply circuit.

2. A short-circuit monitoring arrangement according to claim 1, wherein the phase monitoring unit comprises a plurality of phase monitoring elements each allocated to a respective motor phase and each comprising one output and decoupling stage, arranged on the motor side, a filter element to filter the harmonic voltage, and subsequent evaluating electronics, there being a clearing module which clears the evaluating electronics when a preset motor current actual value is crossed, each evaluating electronics being operable, when a preset value of the harmonic voltage is not reached, to supply to the switching module a cut-out signal for interrupting the motor current supply circuit.

3. A short-circuit monitoring arrangement according to claim 2, wherein each evaluating electronics contains, on the output side, a monitoring relay which reacts during the duration of the presence of the harmonic
voltage and falls-off when it ceases or when there is a
disturbance within other components, the contacts of the
monitoring relays of all the evaluating electronics
circuits being connected in series and coupled to the
switching module so that, when one of the contacts is
opened, the switch of the switching module reacts to
interrupt the motor current supply circuit.

4. A short-circuit monitoring arrangement according
to any one of the preceding claims, wherein the switching
module switch also interrupts the current supply of the
phase monitoring unit during a cut-out duration when a
cut-out signal occurs.

5. A short-circuit monitoring arrangement according
to any one of the preceding claims, wherein the switching
module switch is a magnetic latching relay with
mechanical resetting.

6. A short-circuit monitoring arrangement
substantially as hereinbefore described with reference to
Figures 1 and 2 of the accompanying drawing.

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including the best method of performing it known to us.
proportional to the harmonic voltage and is electrically isolated from the power circuitry, is supplied to the

FIG 2