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Method for tracing a resistive short-circuit , system, module and recording medium for this method

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(56) Related Art
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ABSTRACT

This method for tracing an impedant electrical short-circuit having a non-zero real part, between windings of coils for exciting a multiphase motor, includes the steps consisting in:

- a) controlling (at 122) an inverter/rectifier for causing the motor to operate in multiphase current-generating mode,
- b) controlling (at 124) switches for connecting a resistive load between each pair of phase conductors, this resistive load being capable of allowing detection of an impedant electrical short-circuit having a non-zero real part, at least by comparison of the powers of the fundamental components of currents measured by sensors, and
- c) detecting (at 128, 138) the existence of the short-circuit from the currents measured by the sensors.

Fig. 2

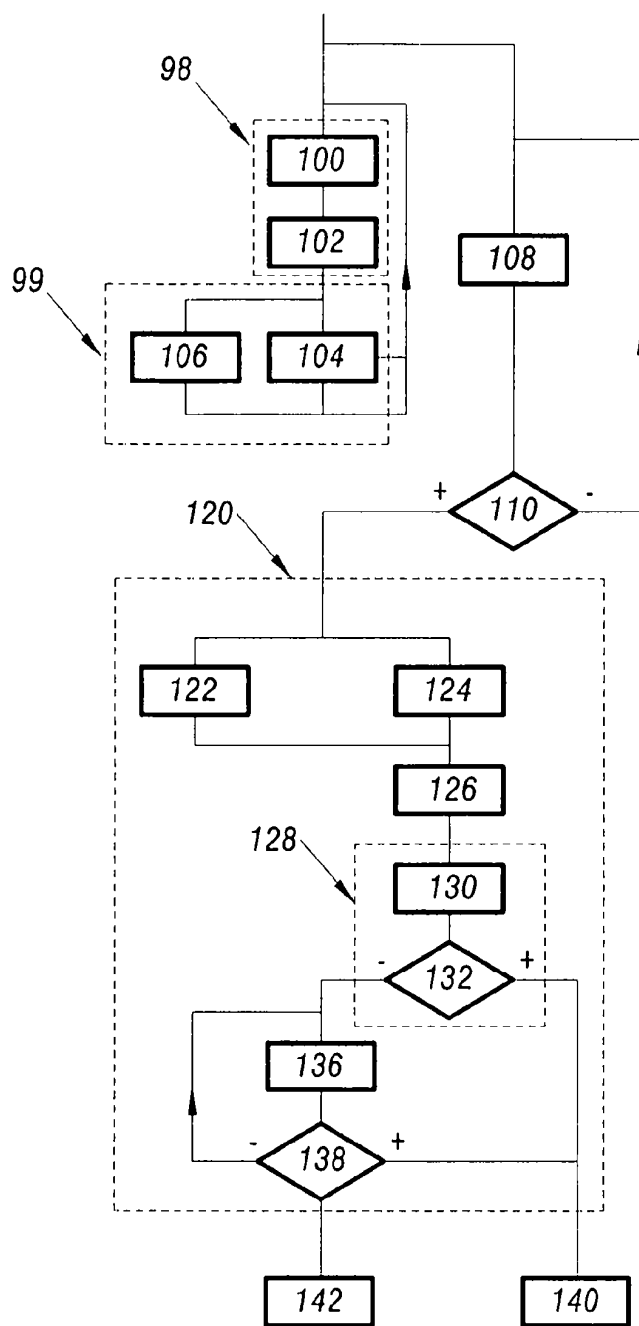


Fig.2

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INVENTION TITLE:

Method for tracing a resistive short-circuit, system, module and recording medium for this method

The following statement is a full description of this invention, including the best method of performing it known to me/us:-

The present invention relates to a method for tracing an impedant short-circuit having a non-zero real part, a system, a module and a recording medium for this method.

There are traction systems for vehicles having:

- a multiphase motor with permanent magnets or a coiled synchronous multiphase motor, this motor having for each phase one or more excitation coils capable of generating a magnetic field for driving in rotation a shaft of the motor,
- phase conductors for connecting the coils of each phase of the motor to a controllable multiphase power source,
- current sensors associated with the phase conductors, these sensors being capable of measuring the current flowing in each phase conductor, and
- a control module capable of controlling the torque of the shaft of the motor as a function of the currents measured by the sensors.

Some of these traction systems are also equipped with at least one resistive load which can be connected between each pair of phase conductors via at least one controllable switch.

The resistive load is often used for dissipating vehicle braking energy or for reducing overvoltages.

An impedant short-circuit is a short-circuit that is established between two motor windings which are normally electrically isolated from each other. However, this short-circuit has a certain impedance. The real part, i.e. the resistive part, of this impedance is typically greater than a few milliohms and generally greater than 10 mΩ. For the sake of simplicity, an impedant short-circuit, the real part of which is not zero, will be referred to for the remainder of the present description as a "resistive short-circuit". The imaginary part of a short-circuit of this type may or may not be zero.

For example, a resistive short-circuit of this type can be obtained when windings of a single motor coil are short-circuited with one another or when windings of two differing coils are short-circuited with one another.

Nowadays, in the event of motor malfunctioning caused by short-circuiting, it is known:

- 1) electrically to connect the ends of all the phase conductors to a common point, or
- 2) electrically to disconnect the phase conductors from the motor.

Solution 1) allows the currents to be balanced in each of the motor phases, despite the existence of the resistive short-circuit. This eliminates or markedly reduces the current passing through the resistive short-circuit. The intensity of the current is therefore strictly the same in each of the phase conductors. No information concerning the existence of a resistive short-circuit can be obtained from measurements of this balanced current.

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If solution 2) is used, no current flows in the phase conductors, so the current sensors cannot be used for detecting the existence of a resistive short-circuit.

Consequently, existing systems also often comprise at least one specific sensor dedicated to detecting a motor fault such as a short-circuit between motor windings.

5 The specific sensors for detecting a resistive short-circuit are not always reliable. In this context, it is desirable to detect a resistive short-circuit without using specific sensors.

The invention seeks to fulfil this wish by providing a method for tracing an impedant electrical short-circuit having a non-zero real part, between windings of coils for
10 exciting a multiphase motor with permanent magnets or a coiled synchronous multiphase motor in an electrical traction system, the traction system comprising:

- the multiphase motor with permanent magnets or the coiled synchronous multiphase motor, this motor having for each phase one or more excitation coils capable of generating a magnetic field for driving in rotation a shaft of the motor,
- 15 - phase conductors for connecting the coils of each phase of the motor to a controllable multiphase power source,
- current sensors associated with the phase conductors, these sensors being capable of measuring the current flowing in each phase conductor,
- a control module capable of controlling the torque of the shaft of the motor as a
20 function of the currents measured by the sensors, and
- at least one resistive load which can be connected between each pair of phase conductors via at least one controllable switch,

characterised in that the method includes the steps consisting in:

- a) controlling the traction system to cause the motor to operate in multiphase
25 current-generating mode,
- b) controlling the controllable switch or switches for connecting the resistive load between each pair of phase conductors, this resistive load being capable of allowing detection of an impedant electrical short-circuit having a non-zero real part, at least by comparison of the powers of the fundamental components of the currents measured by
30 each of the sensors, and

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c) detecting the existence of the electrical short-circuit from the currents measured by the sensors when the resistive load is connected between each pair of phase conductors and the motor is operating in current-generating mode.

In the foregoing method, the same current sensors as those used to control the torque of the motor are used in order to detect the existence of a resistive short-circuit. This method is therefore simpler to carry out, since it does not require the use of specific sensors dedicated to detecting resistive short-circuits.

The embodiments of this tracing method can comprise one or more of the following characteristics:

10 - a step d) for detecting a failure of the traction system without having to cause the motor to operate as a current generator and wherein steps a) to c) are triggered solely in response to the detection of a failure during step d);

- the value of the resistive part of the resistive load is variable and the method includes a step for adjusting the value of this resistive part until the detection of the electrical resistive short-circuit is at least possible by comparison of the powers of the fundamental components of the currents measured by each of the sensors;

15 - the resistive load connected between each pair of phase conductors during step b) is the same as that connected between the phase conductors for dissipating the energy generated by the motor during braking of the motor shaft;

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- the multiphase power source comprises an inverter/rectifier electrically connected, on the one side, to the phase conductors and, on the other side, to a pair of DC voltage conductors and step b) consists in controlling the connection of the resistive load between the DC voltage conductors;

- the resistance of the coil or coils of a single phase of the motor is referred to as the internal resistance and denoted by R_{int} and, during step b), the value of the resistive part of the load connected between each pair of phase conductors is between R_{int} and $200,000.R_{int}$, so that a portion of the current generated by the motor passes through the resistive short-circuit whereas another portion of the current generated by the motor flows in the phase conductors.

These embodiments of the tracing method also have the following advantages:

- using a step for detecting a failure of the traction system before carrying out steps a) to c) allows the number of times the steps are carried out to be limited and therefore the vehicle braking to be limited,

- adjusting the value of the resistive part allows the method to be adapted to the short-circuit to be traced in order to maintain a good level of sensitivity, whatever the impedance of this resistive short-circuit,

- using the same resistive load as that used to dissipate the energy during the vehicle braking also allows the implementation of the calculating method to be simplified, and

- using a resistive load which can be connected between the DC voltage conductors allows implementation of the method to be simplified, as it is then possible to use merely a single switch for connecting the resistive load between each pair of phase conductors.

The invention also relates to a data recording medium comprising instructions for carrying out the foregoing tracing method when these instructions are carried out by an electronic computer.

25 The invention also relates to a vehicle traction system comprising:

- a multiphase motor with permanent magnets or a coiled synchronous multiphase motor, this motor having for each phase one or more excitation coils capable of generating a magnetic field for driving in rotation a shaft of the motor,

- phase conductors for connecting the coils of each phase of the motor to a controllable multiphase power source,

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- current sensors associated with the phase conductors, these sensors being capable of measuring the current flowing in each phase conductor,

- a control module capable of controlling the torque of the shaft of the motor as a function of the currents measured by the sensors,

- at least one resistive load which can be connected between each pair of phase conductors via at least one controllable switch, and

- a diagnostic module capable of carrying out a method for tracing an electrical resistive short-circuit as defined above.

Finally, the invention also relates to a diagnostic module capable of being implemented in the foregoing traction system, wherein the diagnostic module is capable of carrying out the foregoing method for tracing a resistive short-circuit.

The invention will be better understood on reading the following description, given merely by way of non-limiting example and with reference to the drawings, in which:

- Fig. 1 is an illustration of a vehicle equipped with an electrical traction system,
- Fig. 2 is a flow chart of a method for tracing a resistive short-circuit in the traction system of Fig. 1, and
- Fig. 3 is a schematic illustration of the structure of another embodiment of a traction system in which the method of Fig. 2 is carried out.

Fig. 1 shows a vehicle 2 equipped with a traction system 4 capable of driving in rotation drive wheels of the vehicle 2. In the present case, the vehicle 2 is a railway vehicle such as a train.

For the remainder of the present description, the features and operations well known to a person skilled in the art will not be described in detail.

Moreover, for the sake of simplicity, Fig. 1 shows merely one drive wheel 6.

The system 4 is supplied with DC voltage from a catenary 10. More specifically, the system 4 is connected to the catenary 10 via a pantograph 12 and an input coil 13 connected in series with a circuit breaker 14.

The system 4 comprises a three-phase power source formed by a DC voltage supply bus connected to the input of a controllable three-phase inverter/rectifier 20.

The supply bus is, in the present case, formed by two electrical conductors 22 and 24. The conductor 22 is electrically connected to an output of the circuit breaker 14 delivering the supply voltage. The electrical conductor 24 is connected to a reference potential such as earth.

These conductors 22 and 24 are electrically connected by one of their ends to DC voltage inputs 26 and 27 of the inverter/rectifier 20.

The inverter/rectifier 20 comprises three AC voltage outputs 30, 31 and 32 connected, respectively, to phase conductors 34 to 36.

This inverter/rectifier 20 is capable of transforming the DC voltage present between the conductors 22 and 24 into an AC voltage delivered to the outputs 30 to 32 and vice versa.

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The inverter/rectifier 20 is a conventional inverter rectifier equipped with controllable switches such as IGBTs (insulated gate bipolar transistors).

Conventionally, this inverter/rectifier 20 comprises three branches connected in parallel; each branch comprises two controllable switches connected in series, to the terminal of which free wheel diodes are connected in the antiparallel position.

Each conductor 34 to 36 powers stator coils of a respective phase of a three-phase motor 38 with permanent magnets.

Fig. 1 shows, by way of illustration, merely three stator coils 40 to 42 powered respectively by the conductors 34 to 36. These stator coils are capable of producing a magnetic excitation field capable of driving in rotation a rotor 44 equipped with permanent magnets. For the sake of simplicity, Fig. 1 shows merely three permanent magnets 46 to 48.

It will be noted that the internal resistance of the motor 38 is defined as being the resistance of all of the coils of a phase. In the case of a motor mounted in a star-shaped configuration, this resistance can be measured by measuring the resistance of the motor taken between two connection terminals of the phase conductors and by dividing the measured resistance by two, so as to obtain the resistance of the coils of a single phase. The value R_{int} of the internal resistance of a multiphase motor is typically between 5 m Ω and 100 m Ω . For example, the value R_{int} of the internal resistance of the motor 38 is equal to 40 m Ω .

The rotor 44 drives in rotation a shaft 50 which, for its part, drives in rotation, via mechanisms (not shown), the drive wheels of the vehicle 2.

The controllable contactors 52 to 54 allow the phase conductors 34 to 36 to be electrically disconnected from the coils of the motor 38.

A variable resistive load 60 can be connected at the input of the inverter/rectifier 20 between the conductors 22 and 24. It will be noted that connecting a resistive load between the conductors 22 and 24 amounts, from an electrical point of view, to connecting a resistive load between each pair of phase conductors 34 to 36.

The load 60 is designed in such a way that the value of its resistive part, connected between each pair of phase conductors, is between R_{int} and $200,000.R_{int}$, wherein the symbol “.” denotes multiplication. Preferably, the load 60 is designed in such a way that the value of its resistive part, connected between each pair of phase conductors, can vary between R_{int} and $200,000.R_{int}$ or even from R_{int} to $2,000.R_{int}$. In the particular case described, the resistive part, connected between each pair of phase conductors, can vary between 40 m Ω and 8 Ω . Thus, for most resistive short-circuits which can occur, it is possible to adjust the value of the resistive part of the load 60 so that one portion of the current flows in the phase conductors whereas another portion of the current passes through the resistive short-circuit.

In the present case, this load 60 is also intended to dissipate the braking energy when the motor 38 operates as a current generator for braking the vehicle 2.

The load 60 comprises a resistor 62 having a constant value R_H and a rheostatic chopper 64. R_H is in the present case equal to $\frac{2}{3} \cdot R_{int}$. The resistor 62 is connected directly, by one of its ends, to the conductor 24 and, by the other of its ends, to the conductor 22 via the chopper 64. The chopper 64 allows, when activated, the load 60 to be connected to the conductor 22 and, when deactivated, the load 60 to be electrically isolated from the conductor 22. Moreover, the chopper, when activated, allows the value of the resistive part of the load 60 to be varied by chopping the current passing through the resistor 62.

In the present case, this chopper 64 comprises a controllable switch 66 connected in series with a diode 68 via a common point 70.

In the present case, the switch 68 is formed using an IGBT 72, of which the collector is connected directly to the conductor 22 and the transmitter to the point 70. A free wheel diode 74 is connected, in the antiparallel position, to the terminals of the transistor 72.

The cathode of the diode 68 is connected to the point 70 whereas its anode is connected directly to the conductor 24.

The centre point 70 is connected to the resistor 62.

When the chopper 64 is activated, the switching frequency f_c of the switch 66 is between 50 Hz and 10 kHz. For example, in the present case, the frequency f_c is equal to 400 Hz. The opening rate TX of the switch 66 is controllable. In the present case, the opening rate TX can vary between 0.005 and 1.

The opening rate TX of this chopper 64 is defined in the present case using the following equation:

$$TX = \text{ton} \cdot f_c \quad (1)$$

wherein:

- TX is the opening rate
- ton is the time interval during which said switch 66 is on over each period $1/f_c$, and
- f_c is the switching frequency.

The value R_{eq} of the resistive load 60 when the chopper 64 is activated is given by the following equation:

$$R_{eq} = \frac{R_H}{TX} \quad (2)$$

wherein:

- R_{eq} is the value of the resistive part of the load 60,

- RH is the value of the resistor 62, and

- TX is the opening rate.

A filtering capacitor 78 is permanently connected between the conductors 22 and 24.

The system 4 comprises a sensor 80 dedicated solely to detecting a failure of the motor 38. The sensor 80 is capable of measuring characteristics representing the operation of the motor 38. These characteristics allow a failure of the motor to be detected even when the motor is driving the drive wheels in rotation. The sensor 80 is, for example, a detector of vibrations of the motor 38.

The system 4 is also equipped with current sensors capable of measuring the current in each of the phase conductors 34 to 36. Only two current conductors 84 and 86, associated respectively with the conductors 34 and 35, are accordingly used for this purpose in the present case. The value of the current in the conductor 36 can be deduced from the measurements taken by the sensors 84 and 86.

A control module 88 is capable of controlling the torque of the shaft 50 of the motor 38 from the current measurements taken by the sensors 84 and 86. More specifically, the control module 88 controls the inverter/rectifier 20 for this purpose.

The module 88 is also capable of controlling the contactors 52 to 54 as well as the chopper 64.

Finally, the system 4 comprises a diagnostic module 90 capable of detecting a failure of the motor 38 from the measurements of the sensor 80 and also of detecting a resistive short-circuit between windings and coils of this motor from the current measurements taken by the sensor 84 and 86. The module 90 is accordingly capable of controlling the inverter/rectifier 20 and the chopper 64.

The modules 88 and 90 are, for example, produced using a programmable electronic computer 94 capable of carrying out the instructions recorded in a memory 96. The memory 96 accordingly comprises instructions for carrying out the method of Fig. 2 when the instructions are carried out by the computer 94.

The operation of the system 4 will now be described with regard to the method of Fig. 2.

Initially, the system 4 does not display any failure. Under these conditions, phases 98 for driving the vehicle 2 are alternated with vehicle braking phases 99.

During the drive phase 98, the sensors 84 and 86 measure, in a step 100, the current in the phase conductors 34 and 35 and transmit these measurements to the control module 88. Then, during a step 102, the module 88 controls the inverter/rectifier 20 so as to adjust the traction torque exerted by the motor 38 as a function of the measured currents and of a torque setting.

During the vehicle braking phase 99, the module 88 controls, in a step 104, the inverter/rectifier 20 so that the inverter/rectifier operates as a voltage rectifier and the motor 38 operates as a three-phase current generator. During a step 106, simultaneously with the step 104, the module 88 controls the chopper 64 so as to adjust the value of the resistive part of the load 60, so the resistive part dissipates the energy generated by the motor 38 during braking of the vehicle 2.

During a step 108, simultaneously with the phases 98 and 99, the sensor 80 permanently measures characteristics of the motor 38, from which a failure of this motor can be detected. These measurements are analysed in real time, during a step 110, by the diagnostic module 90. If, on the basis of these measurements, the module 90 does not detect a failure of the motor 38, then no particular action is taken and the phases 98 and 99 continue to run normally. In this case, at the end of step 110, the method returns to step 108.

In the opposite case, i.e. if, during step 110, the module 90 detects that there is a failure of the motor 38, then the phases 98 and 99 are interrupted and the method is followed by a phase 120 for tracing a resistive short-circuit between coil windings of the motor 38.

At the start of phase 120, during a step 122, the module 90 controls the inverter/rectifier 20 to cause the motor 38 to operate in three-phase current-generating mode and the inverter/rectifier as a three-phase current rectifier. More specifically, during step 122, the module 90 keeps the IGBTs of the inverter/rectifier 20 open, so the inverter/rectifier behaves like a diode rectifier bridge.

Simultaneously, during a step 124, the module 90 controls the activation of the chopper 64 to connect the load 60 between the conductors 22 and 24. During the step 124, for example, the opening rate TX of the chopper 64 passes directly from the value 0 to the value 1, so the value of the resistive part of the load 60 is minimal.

Thus, at the end of steps 122 and 124, the motor 38 brakes the vehicle 2. Moreover, almost all of the current generated by the motor 38 passes through the phase conductors, as the value of the load 60, connected between the conductors 22 and 24, is substantially equal to R_{int} . Under these conditions, worsening of the motor failure is limited.

Then, during a step 126, the sensors 84 and 86 measure the current flowing in the phase conductors 34 and 35 and transmit these measurements to the module 90.

On the basis of these measurements, the module 90 tries, during a step 128, to detect the existence of a resistive short-circuit. More specifically, during step 128, the module 90 calculates, in an operation 130, the power of the fundamental components of all the phase currents from the measurements taken by the sensors 84 and 86. In the present case, these

fundamental components have a frequency equal to the stator frequency of the motor 38. Then, during an operation 132, the powers thus calculated are compared in pairs.

If the powers of these fundamental current components are substantially equal, then, during step 136, the module 90 controls the chopper 64 to increase the value of the resistive part of the load 60 by a predetermined increment. For example, during step 130, the module 90 reduces the opening rate TX of the rheostatic chopper 64 by a predetermined increment. This predetermined increment is, for example, equal to 0.05.

Then, the control module proceeds to a step 138, during which the module 90 attempts again to detect the existence of a resistive short-circuit. This step 138 is, for example, identical to step 128. If no resistive short-circuit is detected, the method returns to step 136. The module 90 thus gradually increases the value of the resistive part of the load 60 until the value is sufficient for one substantial portion of the current generated by the motor 38 to flow in the phase conductors, whereas another substantial portion of the current passes through the resistive short-circuit. The portion of the current is said to be "substantial" once it allows a short-circuit to be detected from the currents measured by the sensors 84 and 86 by applying a detecting method such as that described with regard to step 128. In this case, if there actually is a short-circuit between windings of the coils of the motor 38, the difference between the powers of the fundamental current components exceeds, for example, a predetermined threshold, and this allows the existence of the resistive short-circuit to be established. Moreover, as a function of the amplitudes of the fundamental components which differ from one another, it is possible to determine which is the phase or phases of the motor 38 affected by the resistive short-circuit.

If, during step 128 or during step 138, it is established that there is a resistive short-circuit, then phase 120 is completed and is followed by a phase 140, during which the driver of the vehicle 2 is informed of the existence of a resistive short-circuit.

If the value of the resistive part of the load 60 reaches its maximum value without it having been possible to detect a resistive short-circuit during step 128 or during step 138, then the method is terminated, during a step 142, and the existence of a resistive short-circuit is not confirmed.

It will be noted that in this particular embodiment, given that the sensors 84 and 86 are positioned upstream of the contactors 52 to 54, the module 90 also allows detection of a short-circuit between these contactors 52 to 54 and of a resistive short-circuit between the phase conductors connecting these conductors 52 to 54 to connection terminals of the motor 38.

Moreover, in the present case, the module 90 is preferably also capable of detecting a failure of the inverter/rectifier, given that the current measured by the sensors 84 and 86 also passes through the inverter/rectifier 20 before reaching the load 60.

Finally, it will be understood that if one substantial portion of the current passes through the resistive short-circuit and the other substantial portion of the current generated by the motor 38 flows in the phase conductors, the current in the phase conductors is a function of the resistive short-circuit established. It is therefore possible, based on the measurements of these phase currents, not only to determine the existence of a resistive short-circuit but also to specify which is/are the phases of the motor 38 affected by this resistive short-circuit.

Fig. 3 shows another embodiment of an electrical traction system 150 of the vehicle 2. In this figure, the elements already described with reference to Fig. 1 are given the same reference numerals.

The system 150 is identical to the system 4 apart from the fact that the resistive load 60 is replaced by a three-phase variable resistive load 152 connected between the phase conductors 34 to 36.

The load 152 is formed by three parallel branches connected, at one of their ends, to a common point 153. The other ends of these branches are connected respectively to the conductors 34, 35 and 36. Each of these branches comprises a resistor, respectively 154 to 156, connected directly, on one side, to the common point 152 and, on the other side, to the phase conductor via a controllable rheostatic chopper 160. The chopper 160 can be controlled by the diagnostic module 90. The value of the resistors 154 to 156 is constant.

The value of the resistors 154 to 156 is chosen to be equal to R_{int} , so the value of the resistive part of the load 152 on each of the branches can vary between R_{int} and $2,000.R_{int}$.

The operation of the system 150 can be deduced from that described with reference to Fig. 2. As in the method of Fig. 2, in the event of a fault being detected from the measurements of the sensor 80, the module 90 adjusts the value of the resistive part of the load 152 so that one substantial portion of the current generated by the motor 38 passes through the resistive short-circuit and another substantial portion flows in the phase conductors. Thus, as in the system 4, the current sensors 84 and 86 can be used for detecting the existence of a resistive short-circuit. However, in this embodiment, the current flowing in the phase conductors does not pass through the inverter/rectifier 20 so that, in this embodiment, failure of this inverter/rectifier 20 cannot be detected.

Numerous other embodiments of the system 4 or the system 150 are possible. For example, the variable resistive part of the resistive load can be produced from a varistor, the value of which varies as a function of the voltage applied between its terminals. The variable resistive part can also be produced using a DC/DC converter.

In the present case, in the system 4, the resistive part used to cause a substantial portion of the current to flow in the phase conductors 34 to 36 is the same as that used during rheostatic

braking for dissipating the energy generated by the motor 38. However, it will be noted that, in these two embodiments, the value of the resistive part is not adjusted in the same way. In the event of rheostatic braking, the value of the resistor 62 is adjusted so as appropriately to dissipate the energy generated by the motor 38 during braking. If the same resistor is used for carrying out the tracing method, its value is adjusted so that a substantial portion of the three-phase current generated by the motor 38 flows in the phase conductors 34 to 36 so that, based on measurements of this current, the module 90 can detect the existence of this resistive short-circuit.

In a variation, instead of the resistor used for dissipating energy during braking of the vehicle 2, a clipping resistor, connected in parallel between the conductors 22 and 24, is used when carrying out the method of Fig. 2. During normal operation of the traction system, the function of this clipping resistor is to clip the overvoltages that can occur between the conductors 22 and 24.

The system has been described in the particular case in which the motor 38 is a motor with permanent magnets. However, the method of Fig. 2 also applies to a traction system in which the traction motor is a coiled synchronous multiphase motor, i.e. a motor comprising coils both on the stator and on the rotor.

In a simplified embodiment, the variable load 60 and the variable load 152 can be replaced by loads, the value of the resistive part of which is constant. In this embodiment, the value of the resistive part of this load is predetermined in advance by simulation or experimentally so that a given speed of the vehicle 2 allows, in the case of most resistive short-circuits, one substantial portion of the current generated by the motor to flow in the phase conductors whereas another substantial portion passes through the resistive short-circuit.

In a variation, once the value of the resistive part, connected between each pair of phase conductors, has been adjusted so that one substantial portion of the current generated by the motor flows in the phase conductors whereas another substantial portion passes through the resistive short-circuit, the presence of the resistive short-circuit can be detected using methods other than that consisting in comparing the power of the fundamental components of the measured currents.

The tracing method described in the present document can apply to traction systems other than those used in a vehicle.

In a simplified embodiment, the sensor 80 can be omitted. In this simplified embodiment, the method for tracing a resistive short-circuit is, for example, triggered on start-up of the traction system. The tracing method can also be triggered if an overcurrent is detected using the sensors 84 and 86.

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The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

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Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

The reference numerals in the following claims do not in any way limit the scope of the respective claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Method for tracing an impedant electrical short-circuit having a non-zero real part, between windings of coils for exciting a multiphase motor with permanent magnets or a coiled synchronous multiphase motor in an electrical traction system, the traction system comprising:

- the multiphase motor (38) with permanent magnets or the coiled synchronous multiphase motor, this motor having for each phase one or more excitation coils capable of generating a magnetic field for driving in rotation a shaft of the motor,

- phase conductors (34 to 36) for connecting the coils of each phase of the motor to a controllable multiphase power source,

- current sensors (84, 86) associated with the phase conductors, these sensors being capable of measuring the current flowing in each phase conductor,

- a control module (88) capable of controlling the torque of the shaft of the motor as a function of the currents measured by the sensors, and

- at least one resistive load (60; 152) which can be connected between each pair of phase conductors via at least one controllable switch,

characterised in that the method includes the steps consisting in:

a) controlling (at 122) the traction system to cause the motor to operate in multiphase current-generating mode,

b) controlling (at 124) the controllable switch or switches for connecting the resistive load between each pair of phase conductors, this resistive load being capable of allowing detection of an impedant electrical short-circuit having a non-zero real part, at least by comparison of the powers of the fundamental components of the currents measured by each of the sensors, and

c) detecting (at 128, 138) the existence of the electrical short-circuit from the currents measured by the sensors when the resistive load is connected between each pair of phase conductors and the motor is operating in current-generating mode.

2. Method according to claim 1, wherein the method includes a step d) for detecting (at 110) a failure of the traction system without having to cause the motor to operate as a current generator and wherein steps a) to c) are triggered solely in response to the detection of a failure during step d).

3. Method according to either of the preceding claims, for a traction system wherein the value of the resistive part of the resistive load is variable and wherein the method includes a step (136) for adjusting the value of this resistive part until the detection of the electrical short-circuit

is at least possible by comparison of the powers of the fundamental components of the currents measured by each of the sensors.

4. Method according to claim 3, wherein the resistive load connected between each pair of phase conductors during step b) is the same as that connected between the phase conductors for dissipating the energy generated by the motor during braking of the motor shaft.

5. Method according to any one of the preceding claims, for a traction system wherein the multiphase power source comprises an inverter/rectifier electrically connected, on the one side, to the phase conductors and, on the other side, to a pair of DC voltage conductors and wherein step b) consists in controlling the connection of the resistive load between the DC voltage conductors.

6. Method according to any one of the preceding claims, for a system wherein the resistance of the coil or coils of a single phase of the motor is referred to as the internal resistance and denoted by R_{int} and wherein, during step b), the value of the resistive part of the load connected between each pair of phase conductors is between R_{int} and $200,000 \cdot R_{int}$, so that one portion of the current generated by the motor passes through the resistive short-circuit whereas another portion of the current generated by the motor flows in the phase conductors.

7. Data recording medium, characterised in that it comprises instructions for carrying out a method according to any one of the preceding claims when these instructions are carried out by an electronic computer.

8. Electrical traction system, this system comprising:

- a multiphase motor (38) with permanent magnets or a coiled synchronous multiphase motor, this motor having for each phase one or more excitation coils capable of generating a magnetic field for driving in rotation a shaft of the motor,

- phase conductors (34 to 36) for connecting the coils of each phase of the motor to a controllable multiphase power source,

- current sensors (84, 86) associated with the phase conductors, these sensors being capable of measuring the current flowing in each phase conductor,

- a control module (88) capable of controlling the torque of the shaft of the motor as a function of the currents measured by the sensors, and

- at least one resistive load (60; 152) which can be connected between each pair of phase conductors via at least one controllable switch,

characterised in that this system also comprises a diagnostic module (90) capable of carrying out a method for tracing an impedant electrical short-circuit having a non-zero real part, according to any one of claims 1 to 6.

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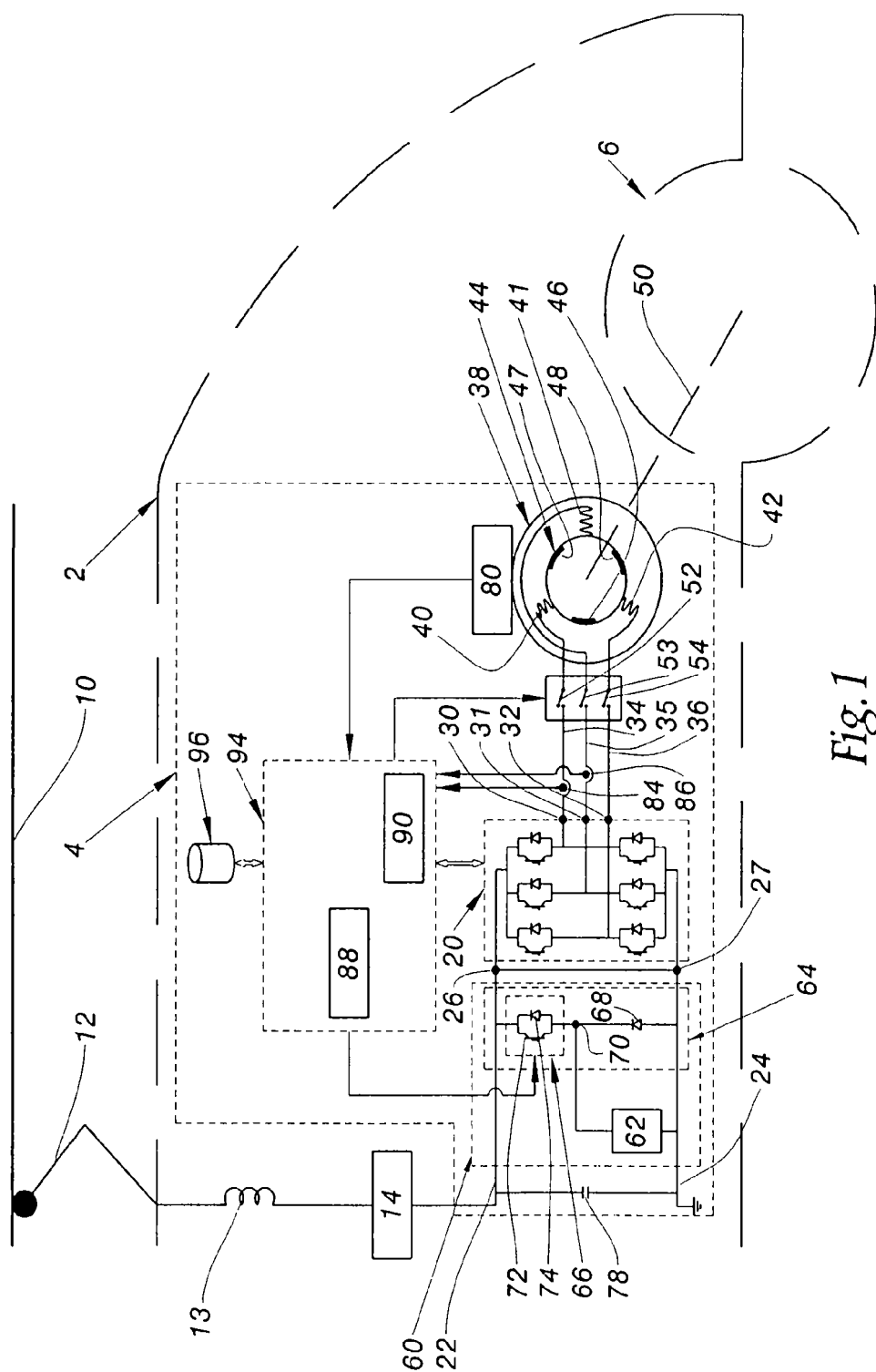
9. Diagnostic module capable of being implemented in a traction system according to claim 8, characterised in that this diagnostic module is capable of carrying out the method for tracing an impedant electrical short-circuit having a non-zero real part, according to any one of claims 1 to 6.

5 10. Method for tracing an impedant electrical short-circuit substantially as hereinbefore described with reference to the accompanying drawings.

11. Electrical traction system substantially as hereinbefore described with reference to the accompanying drawings.

10 12. A data recording medium with instructions for carrying out a method for tracing an impedant electrical short-circuit substantially as hereinbefore described with reference to the accompanying drawings.

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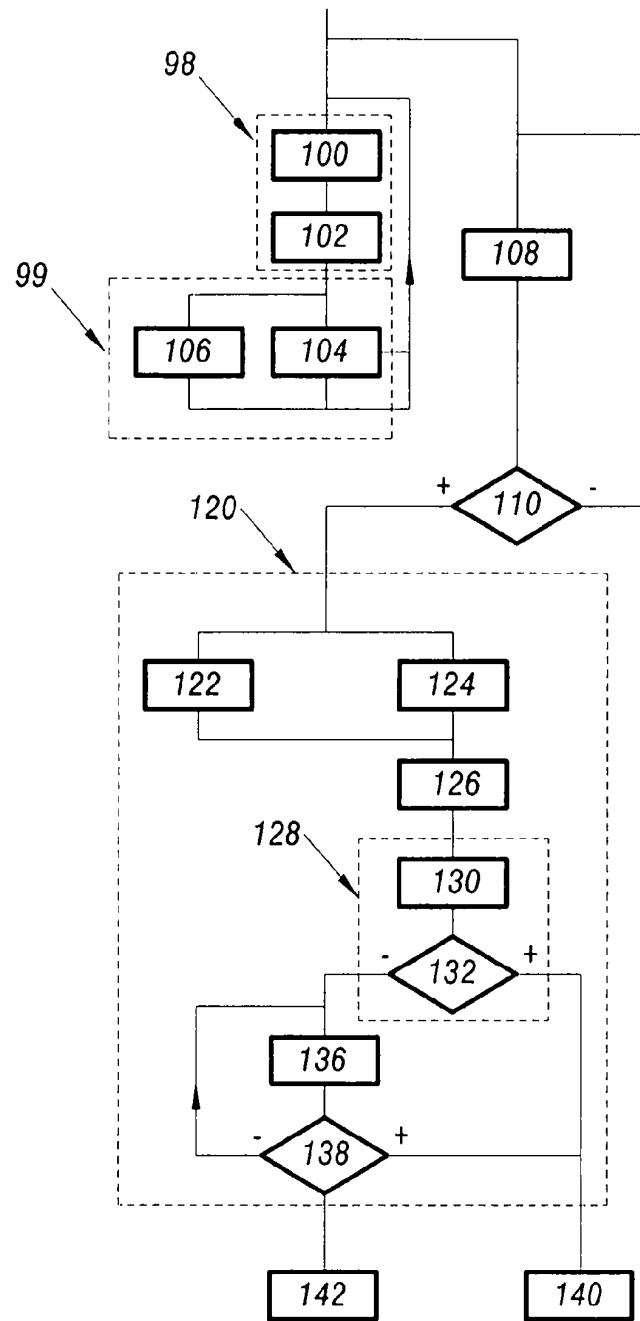


Fig.2

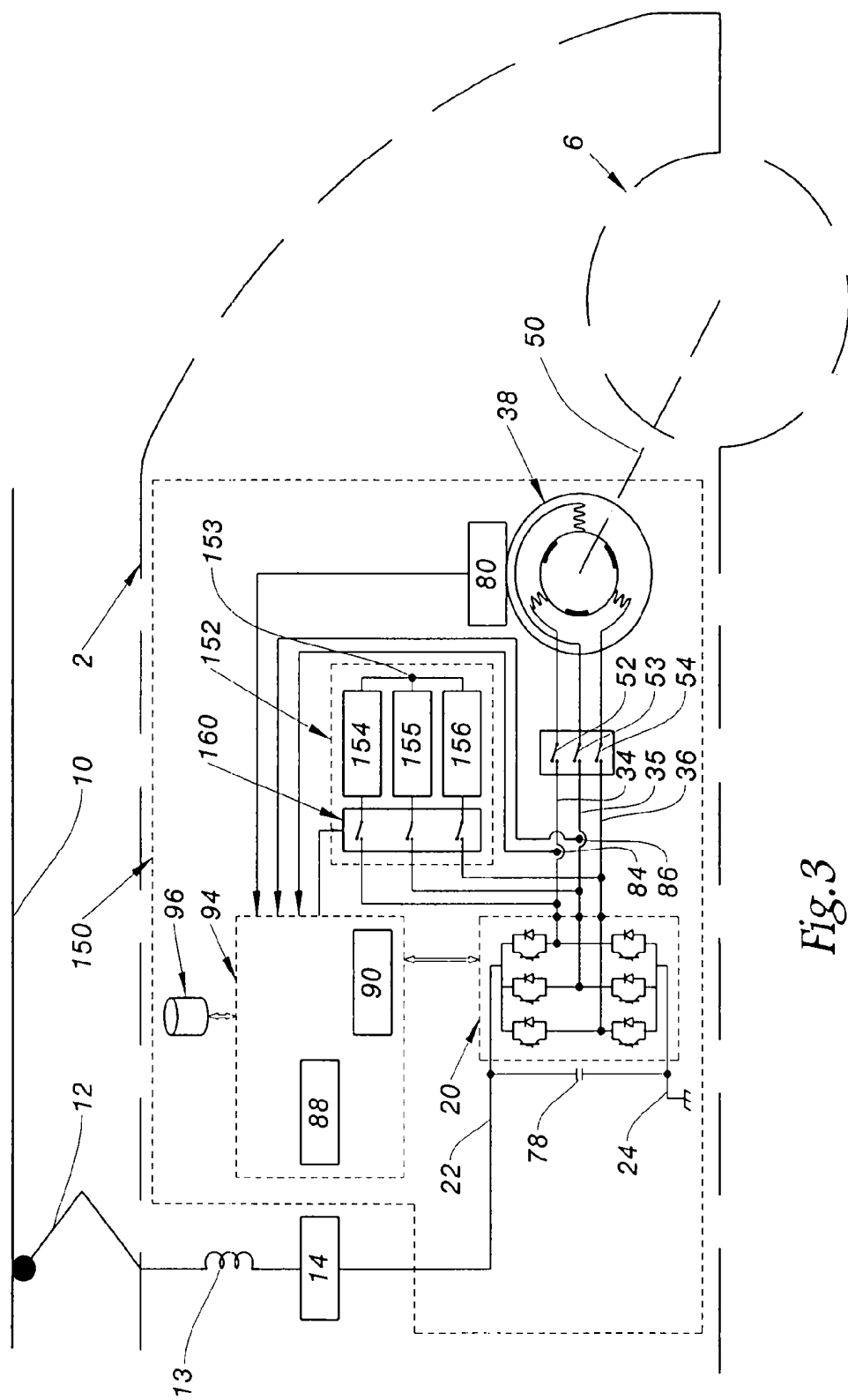


Fig. 3