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(54) LAUNDRY TREATMENT APPLIANCE

(57) A laundry treatment appliance **(100)** is provided. The laundry treatment appliance **(100)** comprises a cabinet **(110)** and a drum **(107)** rotatably accommodated within said cabinet for housing laundry to be treated. The laundry treatment appliance **(100)** further comprises a permanent split capacitor motor **(160)** selectively operable to rotate the drum clockwise and counterclockwise. The permanent split capacitor motor is configured to be supplied by a supply voltage provided across a first supply terminal **(250)** and a second supply terminal **(255)** of an AC power supply. The permanent split capacitor motor comprises a main terminal **(235),** a first control terminal **(240),** and a second control terminal **(245).** The main terminal is coupled with the first supply terminal. The laundry treatment appliance **(100)** further comprises a switching apparatus **(262, 264, 266, 268)** configured to selectively couple:

- the first control terminal with the second supply terminal, while decoupling the second control terminal from the second supply terminal, for rotating the drum clockwise, or
- the second control terminal with the second supply terminal, while decoupling the first control terminal from the second supply terminal, for rotating the drum counterclockwise.

The laundry treatment appliance **(100)** further comprises a voltage sensing unit **(270, 272)** configured to sense the voltage at the first control terminal to produce a corresponding first sensed voltage and to sense the voltage at the second control terminal to produce a corresponding second sensed voltage. The laundry treatment appliance **(100)** further comprises a control unit **(280)** configured to assess an overload condition of the drum based on:

a) the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
b) the second sensed voltage when the first control terminal is coupled with the second supply terminal.

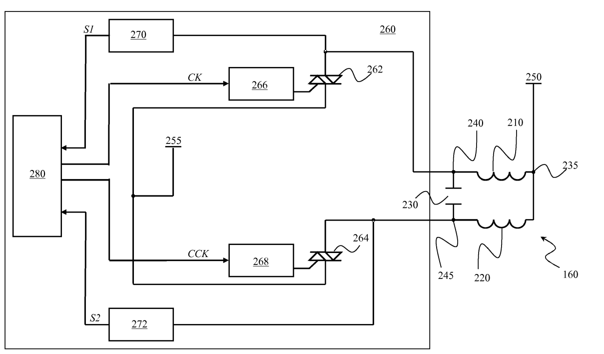

FIG.2

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Description

[0001] The present invention relates to the field of electric motors. More particularly, the present invention relates to the monitoring of electric motors of laundry treatment machines, such as laundry washing machines, laundry drying machines and laundry washing/drying machines comprising rotatable drums arranged for causing agitation of articles to be treated.

[0002] Laundry washing machines, laundry drying machines and laundry washing/drying machines (hereinafter referred to as "laundry treatment appliances") are appliances adapted to treat (e.g., wash and/or dry) clothes, garments, laundry in general.

[0003] Typically, laundry treatment appliances comprise a rotatable drum adapted to receive articles to be treated (e.g., washed and/or dried) for causing agitation of them during the washing and/or drying operations.

[0004] Making for example reference to a laundry drying machine, laundry is dried by circulating hot, dry air within the rotatable drum containing the laundry. In operation, the drum is made to rotate in order to cause agitation of the laundry, which repeatedly tumble with the drum while being invested by the drying air flow.

[0005] In order to improve the laundry treating (*e.g.*, drying) efficiency, laundry treatment appliances are provided with drums configured to rotate in both directions. In this way, the agitation of the laundry contained inside the drum is improved, avoiding that laundry balls up.

[0006] Among the different kinds of AC electric motors that may be employed to rotate the drum of a laundry treatment appliance, the Permanent Split Capacitor Motor (PSCM) is particularly advantageous. Indeed, a PSCM is a particularly reliable single phase motor that need no starting mechanism, and so it can be reversed easily. In this way, the drum can be made to rapidly switch from the clockwise rotation to the counterclockwise rotation (and *viceversa*).

[0007] An important issue of AC electric motors for laundry treatment appliances, such as the PSCM motor, is the motor load, *i.e.*, the mechanical resistance against which the PSCM motor acts for rotating. Indeed, as the load of an AC electric motor increases, in order to keep the rotation speed constant, the motor have to respond by developing an increasing torque, causing a corresponding increase in the motor current. If the load of the AC electric motor becomes excessively high (for example because of an excessive friction due to dryer damage), the motor current increases to such an extent to cause overheating. This issue is particularly dangerous in case the motor load is so high to cause the AC electric motor to block ("locked rotor condition"). Indeed, in this latter case, the overheating may be so high to cause permanent damage to the AC electric motor itself.

[0008] For this purpose, it is known to equip AC electric motors with thermal protection systems, *i.e.,* circuits that are configured to sense the temperature of the AC electric motors and turn off the latter when the sensed temperature exceeds a corresponding safe threshold, in order to avoid that the AC electric motor is damaged. However, thermal protection systems for motors are expensive, and require dedicated temperature sensors.

[0009] Instead of (or in addition to) providing a thermal protection system, known solutions provide for monitoring circuits configured to sense the motor load.

[0010] For example, patent US 6,795,284 discloses a device for stopping the motor when the load on the motor exceeds a predetermined value. It comprises means transforming the voltage variation at the phase-shifting capacitor terminals corresponding to a specific torque variation into a selected voltage variation whatever the maximum torque developed, means comparing the transformed voltage with a reference voltage and means for stopping the motor when the transformed voltage is less than the reference voltage.

[0011] Applicant has observed that the solution disclosed in US 6,795,284 is not particularly efficient for being employed for monitoring the load of a PSCM configured to rotate in both directions. Moreover, the circuit disclosed in US 6,795,284 is quite complex and requires a not negligible amount of additional electronic devices.

[0012] The aim of the present invention is therefore to provide an efficient and simple way to monitor the load of a PSCM configured to rotate in both directions, which is able to detect overload condition in order to prevent any locked rotor condition occurrence.

[0013] An aspect of the present invention proposes a laundry treatment appliance. The laundry treatment appliance further comprises a cabinet and a drum rotatably accommodated within said cabinet for housing laundry to be treated. The laundry treatment appliance further comprises a permanent split capacitor motor selectively operable to rotate the drum clockwise and counterclockwise. The permanent split capacitor motor is configured to be supplied by a supply voltage provided across a first supply terminal and a second supply terminal of an AC power supply. The permanent split capacitor motor comprises a main terminal, a first control terminal, and a second control terminal. The main terminal is coupled with the first supply terminal. The laundry treatment appliance further comprises a switching apparatus configured to selectively couple:

- the first control terminal with the second supply terminal, while decoupling the second control terminal from the second supply terminal, for rotating the drum clockwise, or
- the second control terminal with the second supply terminal, while decoupling the first control terminal from the

second supply terminal, for rotating the drum counterclockwise.

[0014] The laundry treatment appliance further comprises a voltage sensing unit configured to sense the voltage at the first control terminal to produce a corresponding first sensed voltage and to sense the voltage at the second control terminal to produce a corresponding second sensed voltage. The laundry treatment appliance further comprises a control unit configured to assess an overload condition of the drum based on:

a) the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
b) the second sensed voltage when the first control terminal is coupled with the second supply terminal.

[0015] According to an embodiment of the present invention, the control unit is configured to assess the overload condition of the drum based on the amplitude of:

- the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the second sensed voltage when the first control terminal is coupled with the second supply terminal.

[0016] According to an embodiment of the present invention, the control unit is configured to assess the overload condition of the drum based on the assessment of an abrupt decreasing of the amplitude of:

- the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the second sensed voltage when the first control terminal is coupled with the second supply terminal.

[0017] According to an embodiment of the present invention, the control unit is configured to assess the overload condition of the drum when:

- the first sensed voltage falls under an overload threshold when the second control terminal is coupled with the second supply terminal, and
- the second sensed voltage falls under the overload threshold when the first control terminal is coupled with the second supply terminal.

[0018] According to an embodiment of the present invention, the control unit is configured to assess the overload condition of the drum based on the RMS of:

- the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the second sensed voltage when the first control terminal is coupled with the second supply terminal.

[0019] According to an embodiment of the present invention, the control unit is configured quantify the actual load of the permanent split capacitor motor based on a predetermined relationship between the torque developed by the permanent split capacitor motor and:

- the amplitude of the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the amplitude of the second sensed voltage when the first control terminal is coupled with the second supply terminal.

[0020] According to an embodiment of the present invention, the control unit is configured to turn off the permanent split capacitor motor as soon as an overload condition of the drum is assessed.

[0021] According to an embodiment of the present invention, the control unit is configured to turn off the permanent split capacitor motor after a predetermined period from the overload condition assessment.

[0022] According to an embodiment of the present invention, the switching apparatus comprises a first TRIAC having a first conduction terminal connected to the first control terminal and a second conduction terminal connected to the second supply terminal, and a second TRIAC having a first conduction terminal connected to the second control terminal and a second conduction terminal connected to the second supply terminal.

[0023] According to an embodiment of the present invention, the switching apparatus further comprises a driving unit coupled with control terminals of the first TRIAC and of the second TRIAC for:

- turning on the first TRIAC and turning off the second TRIAC for rotating the drum clockwise, or
- turning off the first TRIAC and turning on the second TRIAC for rotating the drum counterclockwise.

[0024] According to an embodiment of the present invention, the permanent split capacitor motor comprises:

- a first winding having a first terminal coupled with the main terminal and a second terminal coupled with the first control terminal;
- a second winding having a first terminal coupled with the main terminal and a second terminal coupled with the second control terminal, and
- a capacitor having a first terminal coupled with the first control terminal and a second terminal coupled with the second control terminal.

[0025] According to an embodiment of the present invention, the laundry treatment appliance is:

- a laundry washing machine;
- a laundry drying machine, or
- a laundry washing/drying machine.

[0026] According to an embodiment of the present invention, the drum is configured to house laundry to be washed and/or dried.

[0027] According to an embodiment of the present invention, the control unit is further configured to quantify a laundry load component of the actual load of the permanent split capacitor motor based on a further predetermined relationship between the torque developed by the permanent split capacitor motor and at least one among:

- the amplitude of the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the amplitude of the second sensed voltage when the first control terminal is coupled with the second supply terminal,

when the drum in not in an overload condition.

[0028] According to an embodiment of the present invention, said control unit is configured to quantify said laundry load component based on a comparison between:

- the amplitude of the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the amplitude of the second sensed voltage when the first control terminal is coupled with the second supply terminal.

[0029] According to an embodiment of the present invention, the switching apparatus comprises:

- a first relay having a first conduction terminal connected to the first control terminal and a second conduction terminal connected to the second supply terminal;
- a second relay having a first conduction terminal connected to the second control terminal and a second conduction terminal connected to the second supply terminal.

[0030] These, and others, features and advantages of the solution according to the present invention will be better understood by reading the following detailed description of some embodiments thereof, provided merely by way of exemplary and non-limitative examples, to be read in conjunction with the attached drawings, wherein:

Figure 1 illustrates in terms of functional blocks a laundry drying machine in which the concepts according to embodiments of the present invention can be applied;

Figure 2 depicts a PSCM of the laundry drying machine of **Figure 1** and a motor control system for controlling the operation of the PSCM according to an embodiment of the present invention;

Figure 3A is a diagram showing an example of how sensed voltage signals generated by the control system of **Figure 2** evolve in time in case the PSCM is driven to rotate clockwise;

Figure 3B is a diagram showing an example of how sensed voltage signals generated by the control system of **Figure 2** evolve in time in case the PSCM is driven to rotate counterclockwise, and

Figure 4 is a diagram showing an exemplary curve corresponding to the RMS of a sensed voltage generated by the control system of **Figure 2** versus the torque developed by the PSCM.

[0031] The concepts of the present invention may be applied to any laundry treatment appliance comprising a PSCM motor configured to rotate both clockwise and counterclockwise, such as laundry washing machines, laundry drying machines and laundry washing/drying machines. In the following there will be described an embodiment of the invention in which the laundry treatment appliance is an exemplary laundry drying machine of the heat pump type.

[0032] With reference to **Figure 1,** the laundry drying machine, which is identified by reference **100,** comprises a laundry treatment chamber **105** including a drum **107** rotatably mounted inside the machine casing or cabinet **110** of the laundry drying machine **100** for accommodating the laundry to be dried. The drum **107** is a generically cylindrical body, for example made of stainless steel, open at the ends thereof.

[0033] The cabinet **110** is generically a parallelepiped in shape, and has a front wall, two side walls, a rear wall, a basement and a top. The front wall is provided with an opening for accessing the laundry treatment chamber **105,** and particularly a front end of the drum **107.** The front wall is further provided with a door **115** for closing the opening. The top closes the cabinet **110** from above, and may also define a worktop.

[0034] Drying air is typically caused to flow through the laundry treatment chamber **105,** and therefore through the drum **107** where the laundry to be dried is contained, and is caused to tumble by the drum **107** rotation. After exiting the laundry treatment chamber **105,** the flow of moisture-laden drying air passes through a moisture condensing system, where the humid, moisture-laden drying air is (at least partially) dried, dehydrated, and the dehydrated air flow is then heated and caused to pass again through the laundry treatment chamber **105,** repeating the cycle.

[0035] Reference numeral **120** denotes a compressor of the heat pump forming the moisture condensing system for the moisture-laden drying air; reference numeral **125** denotes a first heat exchanger, which in the example here considered forms the heat pump evaporator for cooling the drying air and heating the refrigerant; reference numeral **130** denotes a second heat exchanger, which in the example here considered forms the heat pump condenser for heating the drying air and cooling the refrigerant; reference numeral **135** denotes expansion means (*e.g.*, capillary tube, expansion valve) between the evaporator **125** and the condenser **130** of the heat pump; the dashed lines 140 denote the heat pump refrigerant fluid circuit. More generally, the compressor **120,** the first heat exchanger **125,** the expansion means **135** and the second heat exchanger **130** form a refrigerant circuit of the heat pump, which is subdivided into a high pressure portion and a low pressure portion: the high pressure portion extends from the outlet of the compressor **120** via the first heat exchanger **125** to the inlet of the expansion means **135,** whereas the low pressure portion extends from the outlet of the expansion means **135** via the second heat exchanger **130** to the inlet of the compressor **120.** In the considered example, the first heat exchanger **125** acts as an evaporator, and the second heat exchanger **130** acts as a condenser.

[0036] Reference numeral **145** denotes a drying-air recirculation path. Reference numeral **150** denotes a drying-air recirculation fan, which promotes the recirculation of the drying air in the laundry treatment chamber **105** and the drying-air recirculation path **145.** Reference numeral **155** denotes a Joule-effect drying air heater, for example one (or, possibly, more than one) electric resistor that is provided in the drying-air recirculation path **145** for boosting the drying air heating and arranged downstream the second heat exchanger **130.** The heat pump used as a means for condensing the moisture contained in the drying air returning from the laundry treatment chamber **105** is also able to heat up the drying air after it has been de-humidified (the condenser **130** downstream the evaporator **115** has such a function). Preferably, but not limitatively, the recirculation fan **150** is a variable-speed fan.

[0037] The cabinet **110** comprises a drum motor **160** for rotating the drum **107.** For example, the drum motor **160** is housed in the basement of the cabinet **110** and is coupled with the drum **107** by means of a belt transmission **165.** Similar considerations apply to direct-drive arrangements, in which the motor **160** is coaxially mounted with respect to the drum **107** rotation axis.

[0038] According to an embodiment of the present invention, the drum motor **160** is a bidirectional PSCM, *i.e.,* a PSCM configured to rotate both clockwise and counterclockwise.

[0039] A schematic circuit of the PSCM **160** is illustrated in **Figure 2.** The PSCM **160** comprises a first winding **210,** a second winding **220** and a capacitor **230**. The first winding **210** has a first terminal connected to a main terminal **235** of the PSCM **160,** and a second terminal connected to a first control terminal **240** of the PSCM **160**. The second winding **220** has a first terminal connected to the main terminal **235**, and a second terminal connected to a second control terminal **245** of the PSCM **160**. The capacitor **230** comprises a first terminal connected to the first control terminal **240** and a second terminal connected to the second control terminal **245**.

[0040] The PSCM **160** is supplied by means of an AC voltage *Vac* developed across a line terminal **250** and a neutral terminal **255** of an AC power supply, such as the mains voltage power supply. The main terminal **235** of the PSCM **160** is connected to the line terminal **250** of the AC power supply, while the first control terminal **240** and the second control terminal **245** are configured to be mutually exclusively coupled to the neutral terminal **255** of the AC power supply based on the desired rotation direction of the PSCM **160.** For example, when the first control terminal **240** is coupled with the neutral terminal **255** of the AC power supply, the PSCM **160** rotates clockwise, while, when the second control terminal **245** is coupled with the neutral terminal **255** of the AC power supply, the PSCM **160** rotates counterclockwise (similar considerations apply in case the two rotation directions are exchanged).

[0041] The PSCM **160** operation is controlled by means of a motor control system **260**, for example located on a dedicated electronic board inside the laundry drying machine **100** (similar considerations apply if the motor control system is directly located in the main electronic board of the laundry drying machine **100**).

[0042] According to an embodiment of the present invention, the motor control system **260** comprises two TRIACs

262, 264 (TRIode for Alternating Current), two driver units **266, 268,** two voltage sensing units **270, 272,** and a control unit **280,** such as a microcontroller or a microprocessor.

[0043] The TRIAC **262** has a first conduction terminal connected to the first control terminal **240** of the PSCM **160,** a second conduction terminal connected to the neutral terminal **255** of the AC power supply, and a control terminal connected to an output terminal of the driver unit **266.**

[0044] The TRIAC **264** has a first conduction terminal connected to the second control terminal **245** of the PSCM **160,** a second conduction terminal connected to the neutral terminal **255** of the AC power supply, and a control terminal connected to an output terminal of the driver unit **268.**

[0045] The driver unit **266** has an input terminal coupled with the control unit **280** for receiving a driving signal *CK* and an output terminal coupled with the control terminal of the TRIAC **262** for providing TRIAC triggering pulses based on the driving signal *CK.* The driver unit **268** has an input terminal coupled with the control unit **280** for receiving a driving signal *CCK* and an output terminal coupled with the control terminal of the TRIAC **264** for providing TRIAC triggering pulses based on the driving signal *CCK.* For example, the driving signals *CK* and *CCK* are digital signals capable of taking a high value and a low value, and the driver units **266, 268** are configured to generate TRIAC triggering pulses when the corresponding driving signal *CK* or *CCK* is at the high value. Similar considerations apply in case the driver units **266, 268** are configured to generate TRIAC triggering pulses when the corresponding driving signal *CK* or *CCK* is at the low value, or the driving signals *CK* and *CCK* are analog signals. Moreover, the concepts of the present invention apply also in case a single driver unit is provided, configured to provide triggering signals to both the TRIACs **262, 264.**

[0046] In order to drive the PSCM **160** in the clockwise direction, the control unit **280** sets the driving signal *CK* to the high value, while sets the driving signal *CCK* to the low value. In this way, the driver unit **266** generates triggering pulses to activate the TRIAC **262,** while the driver unit **268** not. In this case, the TRIAC **262** is turned on, coupling the first control terminal **240** of the PSCM **160** to the neutral terminal **255** of the AC power supply, while the TRIAC **264** is turned off, insulating the second control terminal **245** of the PSCM **160** from the neutral terminal **255** of the AC power supply.

[0047] In order to drive the PSCM **160** in the counterclockwise direction, the control unit **280** sets the driving signal *CCK* to the high value, while sets the driving signal *CK* to the low value. In this way, the driver unit **268** generates triggering pulses to activate the TRIAC **264,** while the driver unit **266** not. In this case, the TRIAC **264** is turned on, coupling the second control terminal **245** of the PSCM **160** to the neutral terminal **255** of the AC power supply, while the TRIAC **262** is turned off, insulating the first control terminal **240** of the PSCM **160** from the neutral terminal **255** of the AC power supply.

[0048] According to an embodiment of the present invention, the voltage sensing unit **270** has an input terminal coupled with the first control terminal **240** of the PSCM **160** and an output terminal coupled with the control unit **280** for providing a sensed voltage signal *S1* corresponding to the voltage at the first control terminal **240** of the PSCM **160.** The voltage sensing unit **272** has an input terminal coupled with the second control terminal **242** of the PSCM **160** and an output terminal coupled with the control unit **280** for providing a sensed voltage signal *S2* corresponding to the voltage at the second control terminal **242** of the PSCM **160.** Similar considerations apply if a single sensing unit is provided adapted to sense both the voltage at the first control terminal **240** and the voltage at the second control terminal **242.**

[0049] **Figure 3A** is a diagram showing an example of how the sensed voltage signals *S1* and *S2* generated by the voltage sensing units **270, 272** evolve in time in case the PSCM **160** is driven to rotate clockwise. In the considered example, the electronic board **260** wherein the motor control system is located is preferably supplied with a non-insulated power supply, so as to simplify the electronic board architecture. In this case, the TRIAC **262** is driven to be turned on, while the TRIAC **264** is off, so that the first control terminal **240** of the PSCM **160** is connected to the neutral terminal **255** of the AC power supply through the TRIAC **262** while the second control terminal **245** of the PSCM **160** is insulated from the neutral terminal **255.** In this condition, taking the voltage of the neutral terminal **255** of the AC power supply as a voltage reference, the sensed voltage signal *S1* is clamped to the voltage at the neutral terminal **255,** while the sensed voltage signal *S2* oscillates following (with a phase delay) the AC voltage *Vac* developed across the line terminal **250** and the neutral terminal **255** of the AC power supply (not illustrated in figure).

[0050] **Figure 3B** is a diagram showing an example of how the sensed voltage signals *S1* and *S2* generated by the voltage sensing units **270, 272** evolve in time in case the PSCM **160** is driven to rotate counterclockwise. In this case, the TRIAC **264** is driven to be turned on, while the TRIAC **262** is off, so that the second control terminal **245** of the PSCM **160** is connected to the neutral terminal **255** of the AC power supply through the TRIAC **264** while the first control terminal **240** of the PSCM **160** is insulated from the neutral terminal **255.** In this condition, the sensed voltage signal *S2* is clamped to the voltage at the neutral terminal **255,** while the sensed voltage signal *S1* oscillates following (with a phase delay) the AC voltage *Vac* developed across the line terminal **250** and the neutral terminal **255** of the AC power supply (not illustrated in figure).

[0051] Applicant has found that a relationship occurs between the actual load of the PSCM **160** (in term of torque developed by the PSCM **160**) and the amplitude of the voltage at the control terminal of the PSCM **160** which is actually disconnected from the neutral terminal **255** of the AC power supply.

[0052] For this purpose, according to an embodiment of the present invention, the control unit **280** is configured to monitor the load of the PSCM **160** based on:

- the sensed voltage *S1* when the second control terminal **245** of the PSCM **160** is connected to the neutral terminal **255** of the AC power supply through the TRIAC **264,** *i.e.,* when the PSCM **160** is driven to rotate counterclockwise, and
- the sensed voltage *S2* when the first control terminal **240** of the PSCM **160** is connected to the neutral terminal **255** of the AC power supply through the TRIAC **262,** *i.e.,* when the PSCM **160** is driven to rotate clockwise.

[0053] Applicant has found that as the torque developed by the PSCM **160** increases, the amplitude of the voltage at the control terminal of the PSCM **160** which is actually disconnected from the neutral terminal **255** of the AC power supply correspondingly decreases. By observing the way such amplitude decreases as the torque developed by the PSCM **160** increases, Applicant has found that an abrupt amplitude decreasing can be observed at an overload condition of the drum **107** occurring before the load of the PSCM **160** is so high to cause the latter to enter in a locked rotor condition.

[0054] According to an embodiment of the present invention, the control unit **280** is configured to quantify the actual load of the PSCM **160** by measuring the amplitude of the voltage at the control terminal of the PSCM **160** which is actually disconnected from the neutral terminal **255** of the AC power supply, and to assess the occurrence of an overload condition of the drum **107** by identifying possible abrupt amplitude decreasing in the measured voltage.

[0055] According to an embodiment of the present invention, the control unit **280** is configured to calculate the Root Mean Square (RMS) of the sensed voltage *S1* (when the PSCM **160** is driven to rotate counterclockwise) or of the sensed voltage *S2* (when the PSCM **160** is driven to rotate clockwise) and to quantify the actual load of the PSCM **160** and to assess the occurrence of an overload condition of the drum **107** based on the calculated RMS.

[0056] In the following table there is shown an example of how the RMS and the phase of the sensed voltage *S1* vary as the torque developed by the PSCM **160** increases during counterclockwise rotation.

TORQUE (N·m)	S1 AMPLITUDE (RMS)	S1 PHASE (ms)
0	278	5,215
0,2	273	5,154
0,4	257	5,068
0,6	238	4,943
0,8	212	4,843
0,9	184	4,821
0,92	55,9	

[0057] **Figure 4** is a diagram showing a curve corresponding to the RMS of the sensed voltage *S1* versus the torque developed by the PSCM **160** according to the exemplary table reported above.

[0058] From the diagram illustrated in **Figure 4** it can be inferred that until the torque developed by the PSCM **160** is lower than a torque threshold *TTH* corresponding to an overload condition of the drum **107,** the slope of the RMS curve is substantially small, while as the torque developed by the PSCM **160** exceeds said torque threshold *TTH,* the slope of the RMS is subjected to an abrupt decrease.

[0059] According to an embodiment of the present invention, the control unit **280** is configured to quantify the actual load of the PSCM **160** based on a predetermined relationship between the torque developed by the PSCM **160** and the RMS of the sensed voltage *S1* (if the PSCM **160** is driven to rotate counterclockwise) or the RMS of the sensed voltage *S2* (if the PSCM **160** is driven to rotate clockwise), like the relationship depicted in the exemplary table reported above. For example, such predetermined relationship may be calculated as a result of measuring operations carried out during the appliance manufacturing.

[0060] According to an embodiment of the present invention, the control unit **280** is configured to assess the occurrence of an overload condition of the drum **107** as soon as the RMS of the sensed voltage *S1* or *S2* falls below an overload threshold *OTH* indicative of the overload condition and corresponding to the torque threshold *TTH.*

[0061] In this way, the control unit **280** may safely turn off the PSCM **160** (*e.g.*, by setting both the driving signals *CK* and *CCK* to the low value) before the locked condition occurs, avoiding the need of a dedicated thermal protection circuit.

[0062] According to another embodiment of the present invention, the control unit **208** may be designed to turn off the PSCM **160** (*e.g.*, by setting both the driving signals *CK* and *CCK* to the low value) after a predetermined (safe) period from an overload condition assessment.

[0063] In the example at issue, the overload condition which triggers the turning off of the PSCM **160** corresponds to a torque threshold *TTH* between 0,8 and 0,9 N·m, and to an overload threshold *OTH* of about 200 RMS. Moreover, in this example the rotor locked condition occurs when the RMS of the sensed voltage *S1* is decreased down to 55,9.

[0064] According to another embodiment of the present invention, the control unit **280** is configured to assess the occurrence of an overload condition of the drum **107** as soon as the RMS of the sensed voltage *S1* or *S2* is subjected to an abrupt fall, for example by exploiting a known slope detection procedure.

[0065] According to another embodiment of the present invention, the control unit **280** is configured to quantify the actual load of the PSCM **160** and to assess the occurrence of an overload condition of the drum **107** by monitoring the peak amplitude of the sensed voltages *S1, S2* (such as for example by exploiting a peak detection procedure) instead of the RMS thereof.

[0066] According to an embodiment of the present invention, the control unit **280** is further configured to quantify the component of the actual load of the PSCM **160** due to the laundry accommodated in the drum **107** (hereinafter, "laundry load component"). It is underlined that the laundry load component depends on the amount of laundry accommodated in the drum **107** as well as on the amount of water impregnating the laundry itself.

[0067] According to an embodiment of the present invention, the control unit **280** is configured to quantify said laundry load component based on at least one among the calculated RMS of the sensed voltage(s) *S1* and/or *S2* when the drum **107** is not in an overload condition (*e.g.*, as long as the torque developed by the PSCM **160** is lower than the torque threshold *TTH*).

[0068] For example, according to an embodiment of the present invention, the control unit **280** is configured to quantify said laundry load component based on a predetermined relationships between the torque developed by the PSCM **160** and the RMS of the sensed voltage *S1* (if the PSCM **160** is driven to rotate counterclockwise) or the RMS of the sensed voltage *S2* (if the PSCM **160** is driven to rotate clockwise).

[0069] According to another embodiment of the present invention, a more precise assessment of the laundry load component is carried out by comparing the RMS of the sensed voltage *S1* (when the PSCM **160** is driven to rotate counterclockwise) with the RMS of the sensed voltage *S2* (when the PSCM **160** is driven to rotate clockwise). Indeed, the PSCM **160** behavior is influenced by its rotation direction, being usually mounted coaxially with a vent (not illustrated) having a preferred rotation direction. By comparing the RMS of the sensed voltage *S1* - obtained when the PSCM **160** is rotating counterclockwise - with the RMS of the sensed voltage S2 - obtained when the PSCM **160** is rotating clockwise - it is possible to quantify the component of the load given by such vent, and isolating it from the desired laundry load component.

[0070] Naturally, in order to satisfy local and specific requirements, a person skilled in the art may apply to the solution described above many logical and/or physical modifications and alterations.

[0071] For example, similar considerations apply in case instead of TRIACs, different switching devices are used to selectively couple the first control terminal **240** and the second control terminal **245** of the PSCM **160** to the neutral terminal **255,** such as for example power transistors or relays.

[0072] Moreover, the concepts of the present invention may be applied to different type of laundry drying machines, such as condenser laundry machines of the type comprising an air-air exchanger and an heating resistor, as well as venting laundry machines having an open ventilation circuit.

Claims

1. A laundry treatment appliance (**100**), comprising:

- a cabinet (**110**);
- a drum (**107**) rotatably accommodated within said cabinet for housing laundry to be treated;
- a permanent split capacitor motor (**160**) selectively operable to rotate the drum clockwise and counterclockwise, the permanent split capacitor motor being configured to be supplied by a supply voltage provided across a first supply terminal (**250**) and a second supply terminal (**255**) of an AC power supply, the permanent split capacitor motor comprising a main terminal (**235**), a first control terminal (**240**), and a second control terminal (**245**), the main terminal being coupled with the first supply terminal;
- a switching apparatus (**262, 264, 266, 268**) configured to selectively couple:
    - the first control terminal with the second supply terminal, while decoupling the second control terminal from the second supply terminal, for rotating the drum clockwise, or
    - the second control terminal with the second supply terminal, while decoupling the first control terminal from the second supply terminal, for rotating the drum counterclockwise;
- a voltage sensing unit (**270, 272**) configured to sense the voltage at the first control terminal to produce a corresponding first sensed voltage and to sense the voltage at the second control terminal to produce a corre-

sponding second sensed voltage;
- a control unit (**280**) configured to assess an overload condition of the drum based on:

a) the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
b) the second sensed voltage when the first control terminal is coupled with the second supply terminal.

2. The laundry treatment appliance of claim 1, wherein the control unit (**280**) is configured to assess the overload condition of the drum based on the amplitude of:

- the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the second sensed voltage when the first control terminal is coupled with the second supply terminal.

3. The laundry treatment appliance of claim 1 or 2, wherein the control unit (**280**) is configured to assess the overload condition of the drum based on the assessment of an abrupt decreasing of the amplitude of:

- the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the second sensed voltage when the first control terminal is coupled with the second supply terminal.

4. The laundry treatment appliance of any one among the preceding claims, wherein the control unit (**280**) is configured to assess the overload condition of the drum when:

- the first sensed voltage falls under an overload threshold when the second control terminal is coupled with the second supply terminal, and
- the second sensed voltage falls under the overload threshold when the first control terminal is coupled with the second supply terminal.

5. The laundry treatment appliance of any one among the preceding claims, wherein the control unit (**280**) is configured to assess the overload condition of the drum based on the RMS of:

- the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the second sensed voltage when the first control terminal is coupled with the second supply terminal.

6. The laundry treatment appliance of any one among the preceding claims, wherein the control unit (**280**) is configured quantify the actual load of the permanent split capacitor motor based on a predetermined relationship between the torque developed by the permanent split capacitor motor and:

- the amplitude of the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the amplitude of the second sensed voltage when the first control terminal is coupled with the second supply terminal.

7. The laundry treatment appliance of any one among the preceding claims, wherein the control unit is configured to turn off the permanent split capacitor motor:

- as soon as an overload condition of the drum is assessed or
- after a predetermined period from the overload condition assessment.

8. The laundry treatment appliance of any one among the preceding claims, wherein the switching apparatus comprises:

- a first TRIAC (**262**) having a first conduction terminal connected to the first control terminal and a second conduction terminal connected to the second supply terminal;
- a second TRIAC (**264**) having a first conduction terminal connected to the second control terminal and a second conduction terminal connected to the second supply terminal.

9. The laundry treatment appliance of claim 8, wherein the switching apparatus further comprises a driving unit (**266, 268**) coupled with control terminals of the first TRIAC (**262**) and of the second TRIAC (**264**) for:

- turning on the first TRIAC (**262**) and turning off the second TRIAC (**264**) for rotating the drum clockwise, or

- turning off the first TRIAC (**262**) and turning on the second TRIAC (**264**) for rotating the drum counterclockwise.

10. The laundry treatment appliance of any one among the preceding claims, wherein the permanent split capacitor motor comprises:

- a first winding (**210**) having a first terminal coupled with the main terminal and a second terminal coupled with the first control terminal;
- a second winding (**220**) having a first terminal coupled with the main terminal and a second terminal coupled with the second control terminal, and
- a capacitor (**230**) having a first terminal coupled with the first control terminal and a second terminal coupled with the second control terminal.

11. The laundry treatment appliance of any one among the preceding claims, wherein the laundry treatment appliance is:

- a laundry washing machine;
- a laundry drying machine, or
- a laundry washing/drying machine,

the drum being configured to house laundry to be washed and/or dried.

12. The laundry treatment appliance of claim 6 and of any one among claims 1 to 5 when depending on claim 6, wherein the control unit (**280**) is further configured to quantify a laundry load component of the actual load of the permanent split capacitor motor based on a further predetermined relationship between the torque developed by the permanent split capacitor motor and at least one among:

- the amplitude of the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the amplitude of the second sensed voltage when the first control terminal is coupled with the second supply terminal,

when the drum (**107**) in not in an overload condition.

13. The laundry treatment appliance of claim 13, wherein said control unit (**280**) is configured to quantify said laundry load component based on a comparison between:

- the amplitude of the first sensed voltage when the second control terminal is coupled with the second supply terminal, and
- the amplitude of the second sensed voltage when the first control terminal is coupled with the second supply terminal.

14. The laundry treatment appliance of claim of any one among claims 1 to 7, wherein the switching apparatus comprises:

- a first relay having a first conduction terminal connected to the first control terminal and a second conduction terminal connected to the second supply terminal;
- a second relay having a first conduction terminal connected to the second control terminal and a second conduction terminal connected to the second supply terminal.

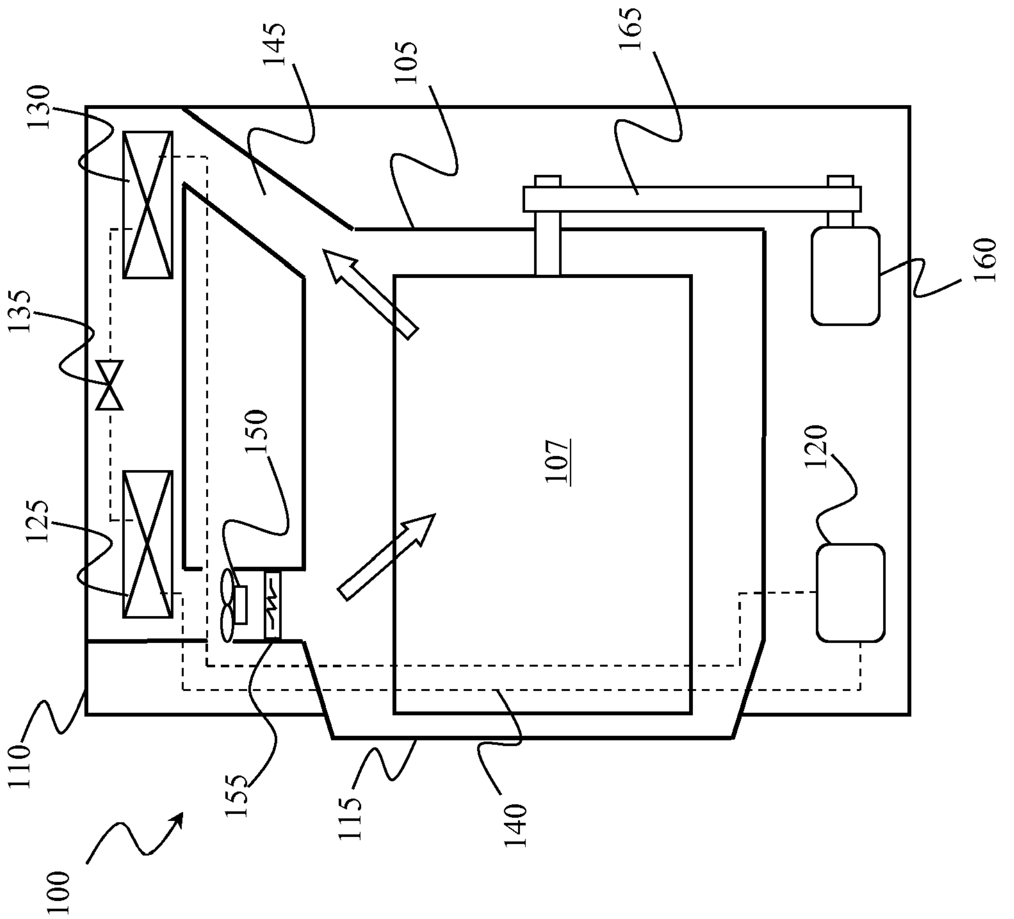


FIG.1

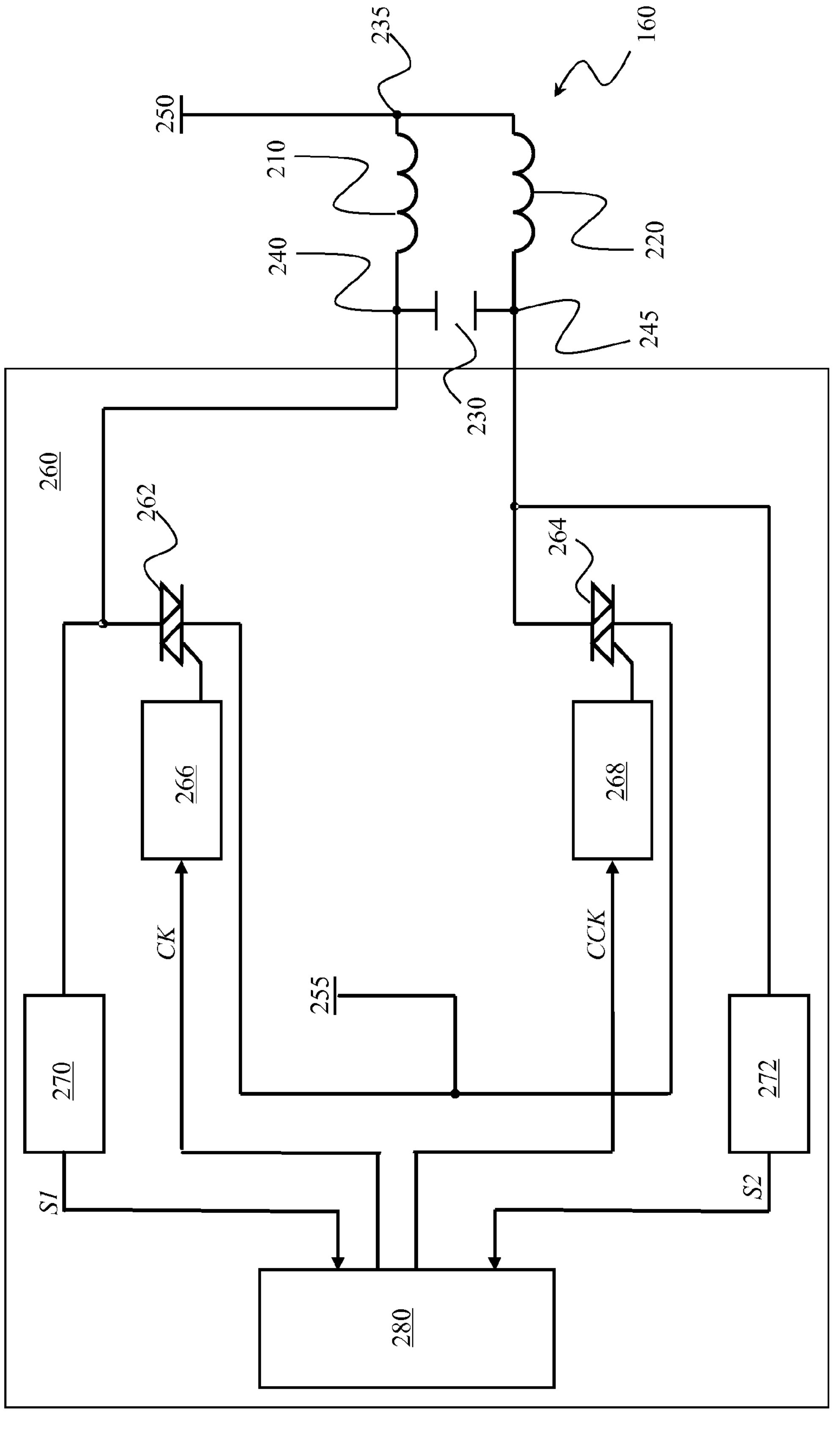

160
235
250
210
220
240
245
230
260
262
264
266
268
CK
CCK
255
270
272
S1
S2
280

FIG.2

FIG.3A

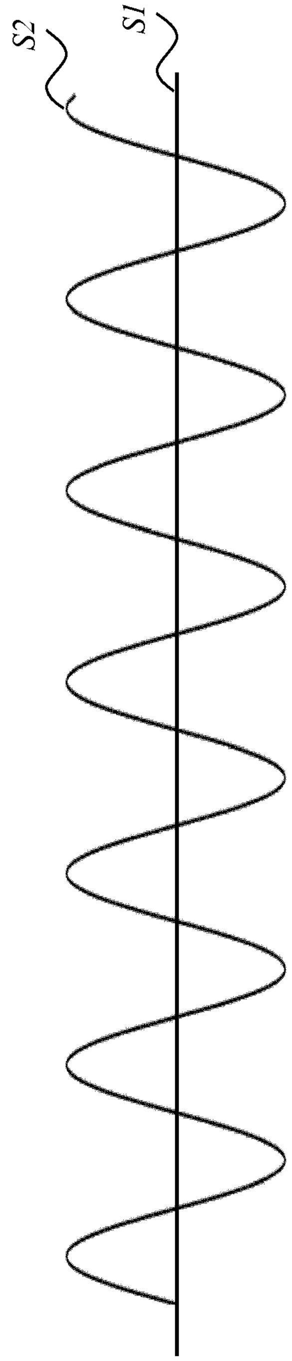
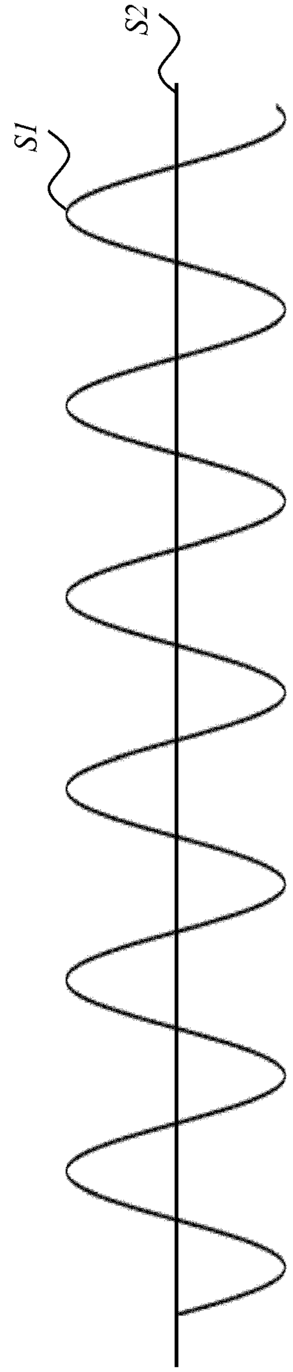


FIG.3B



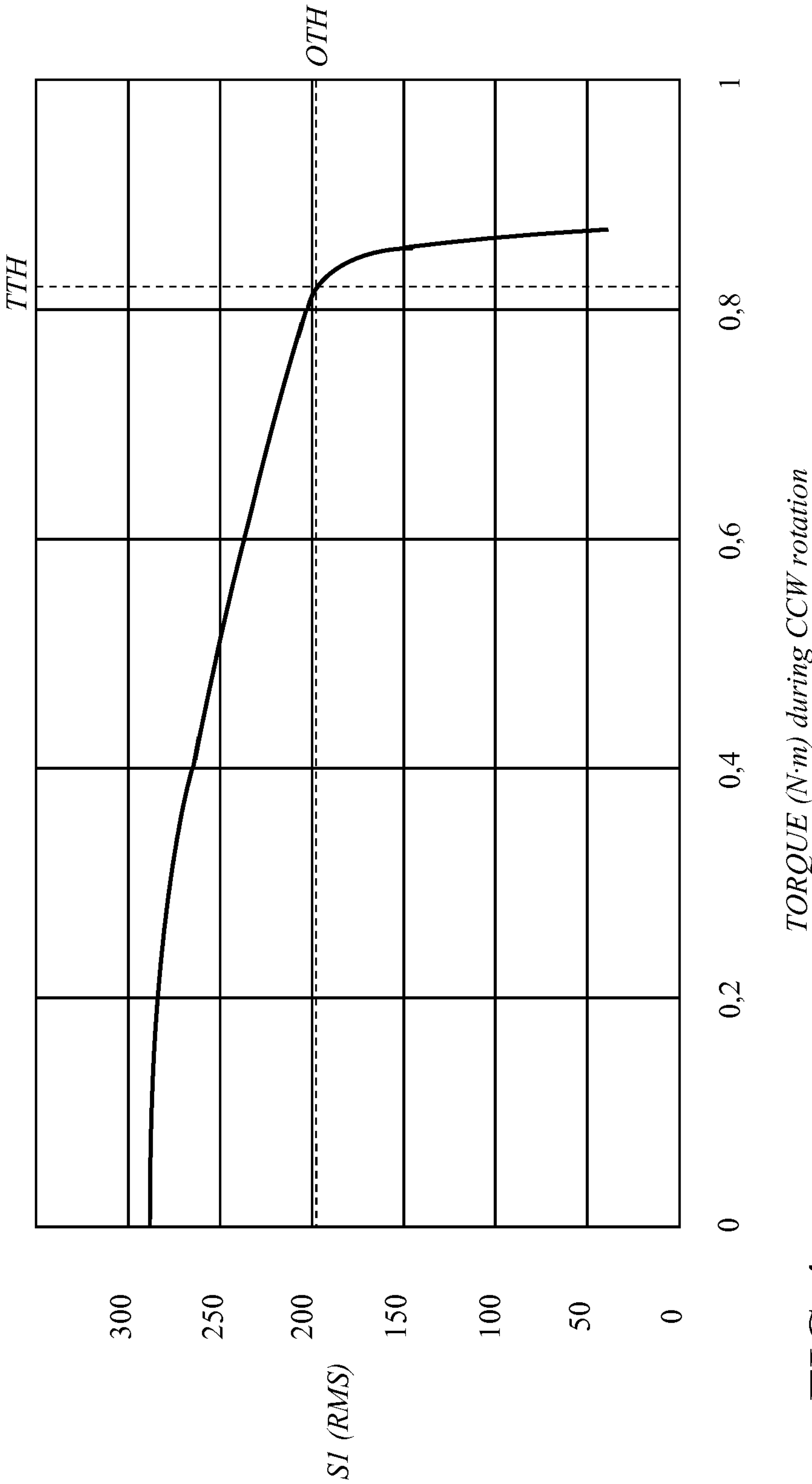

OTH
TTH
S1 (RMS)
300
250
200
150
100
50
0
0
0,2
0,4
0,6
0,8
1
TORQUE (N·m) during CCW rotation

FIG.4

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EUROPEAN SEARCH REPORT

Application Number
EP 16 17 0779

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
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