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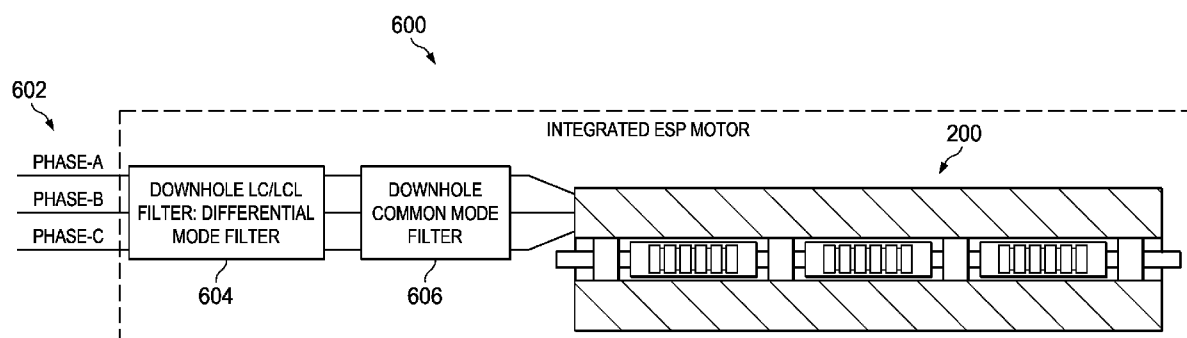


FIG. 6a

(57) Abstract: Embodiments of the present disclosure are directed to a downhole motor including a housing, a rotor shaft configured to rotate within the housing, and an electrically conductive brush. The electrically conductive brush is coupled to the rotor shaft and configured to be biased radially outward and into electrical contact with the housing.

SYSTEM AND METHOD FOR REDUCING MOTOR BEARING CURRENTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED
RESEARCH OR DEVELOPMENT

[0002] Not applicable.

BACKGROUND

[0003] Some oil and gas production rigs employ an artificial lift electrical submersible pump (ESP) to increase pressure within a reservoir to thereby encourage oil to the surface. When the natural drive energy of the reservoir is not sufficient to push the oil to the surface, artificial lift is employed to recover more production. An artificial lift system often includes an electric submersible pump (ESP) driven by an induction motor. The ESP, including the induction motor, is placed downhole and the motor is driven by an electric current produced by surface power equipment.

[0004] Downhole ESPs and their motors operate in harsh environments and may fail over time. Even if such equipment does not completely fail, the performance of the motor and ESP may be impaired due to mechanical wear or failure caused by bearing wear, which may be accelerated when a current path exists across the motor bearings. For example, the induction motor may be a three-phase motor that receives its power supply over a long cable from a variable speed drive (VSD) at the surface. The VSD switching generally contributes differential mode as well as common mode electromagnetic interference (EMI) noise that is transmitted to the ESP motor, which may result in a voltage differential between a motor shaft and the motor housing, leading to an induced current path across the motor bearings and motor insulation discharge (insulation aging). Further, in certain cases, a magnetic imbalance due to geometric imperfections in the motor

may also lead to an induced current path across the motor bearings and motor insulation due to induced high-frequency voltages in the motor shaft and bearings. The high-frequency EMI from the VSD is amplified due to the presence of a long cable and creates high-frequency spikes at motor terminals, causing damage to the motor insulation as well as insulation discharge (or partial discharge), which combine to speed the aging of motor insulation. In any case, the current path across the motor bearings may lead to mechanical wear (*e.g.*, pitting on the bearing surface), while discharge through the motor insulation leads to accelerated degradation of the insulation, both of which decrease the lifespan of the bearings, insulation, and the ESP motor itself.

SUMMARY

[0005] Embodiments of the present disclosure are directed to a downhole motor including a housing, a rotor shaft configured to rotate within the housing, and an electrically conductive brush. The electrically conductive brush is coupled to the rotor shaft and configured to be biased radially outward and into electrical contact with the housing.

[0006] Other embodiments of the present disclosure are directed to a downhole motor including a housing having a base and a rotor shaft configured to rotate within the housing. The rotor shaft includes an end surface proximate to the base. The downhole motor also includes an electrically conductive element coupled to the base and configured to be biased toward and into electrical contact with the end surface of the rotor shaft.

[0007] Still other embodiments of the present disclosure are directed to a system including a downhole motor. The downhole motor includes motor terminals and is configured to receive power from a multi-phase power drive by way of a plurality of cables. The multi-phase power drive introduces an electromagnetic noise component that is transmitted to the downhole motor by way of the plurality of cables. The system also includes a filter proximate and coupled to the motor

terminals and configured to reduce the electromagnetic noise component transmitted to the downhole motor.

[0008] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Embodiments of the disclosure are described with reference to the following figures:

[0010] FIG. 1 illustrates an electric submersible pump including an induction motor deployed in a wellbore environment in accordance with various embodiments of the present disclosure;

[0011] FIG. 2 shows an example of an induction motor including multiple radial bearings in accordance with various embodiments of the present disclosure;

[0012] FIGS. 3a and 3b show perspective and cross-sectional views of a motor having a shaft including one or more brushes in accordance with various embodiments of the present disclosure;

[0013] FIG. 4 shows a cross sectional view of a motor including an electrically conductive element coupled to a base of the motor and in contact with a shaft in accordance with various embodiments of the present disclosure;

[0014] FIG. 5 shows an exemplary electric submersible pump string including an induction motor and a downhole filter coupled to the motor terminals in accordance with various embodiments of the present disclosure;

[0015] FIGS. 6a and 6b show exemplary downhole filters coupled to the motor terminals in accordance with various embodiments of the present disclosure; and

[0016] FIGS. 7a and 7b show an exemplary 3-phase common mode inductor and exemplary flux linkage physics, respectively, in accordance with various embodiments of the present disclosure.

DETAILED DESCRIPTION

[0017] One or more embodiments of the present disclosure are described below. These embodiments are merely examples of the presently disclosed techniques. Additionally, in an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such implementation, as in any engineering or design project, numerous implementation-specific decisions are made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such development efforts might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0018] When introducing elements of various embodiments of the present disclosure, the articles “a,” “an,” and “the” are intended to mean that there are one or more of the elements. The embodiments discussed below are intended to be examples that are illustrative in nature and should not be construed to mean that the specific embodiments described herein are necessarily preferential in nature. Additionally, it should be understood that references to “one embodiment” or “an embodiment” within the present disclosure are not to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. The drawing figures are not necessarily to scale. Certain features and components disclosed herein may be shown exaggerated in scale or in somewhat schematic form, and some details of conventional elements may not be shown in the interest of clarity and conciseness.

[0019] The terms “including” and “comprising” are used herein, including in the claims, in an open-ended fashion, and thus should be interpreted to mean “including, but not limited to...” Also, the term “couple” or “couples” is intended to mean either an indirect or direct connection. Thus, if a first component couples or is coupled to a second component, the connection between the components may be through a direct engagement of the two components, or through an indirect connection that is accomplished via other intermediate components, devices and/or connections. If the connection transfers electrical power or signals, the coupling may be through wires or other modes of transmission. In some of the figures, one or more components or aspects of a component may be not displayed or may not have reference numerals identifying the features or components that are identified elsewhere in order to improve clarity and conciseness of the figure.

[0020] Electric submersible pumps (ESPs) may be deployed for any of a variety of pumping purposes. For example, where a substance does not readily flow responsive to existing natural forces, an ESP may be implemented to artificially lift the substance. Commercially available ESPs (such as the REDA™ ESPs marketed by Schlumberger Limited, Houston, Tex.) may find use in applications that require, for example, pump rates in excess of 4,000 barrels per day and lift of 12,000 feet or more.

[0021] To improve ESP operations, an ESP may include one or more sensors (e.g., gauges) that measure any of a variety of phenomena (e.g., temperature, pressure, vibration, etc.). A commercially available sensor is the Phoenix MultiSensor™ marketed by Schlumberger Limited (Houston, Tex.), which monitors intake and discharge pressures; intake, motor and discharge temperatures; and vibration and current leakage. An ESP monitoring system may include a supervisory control and data acquisition system (SCADA). Commercially available surveillance systems include the LiftWatcher™ and the LiftWatcher™ surveillance systems marketed by

Schlumberger Limited (Houston, Tex.), which provides for communication of data, for example, between a production team and well/field data (*e.g.*, with or without SCADA installations). Such a system may issue instructions to, for example, start, stop or control ESP speed via an ESP controller.

[0022] As explained above, an induction motor drives the ESP. A common type of induction motor is a three-phase motor that receives its power supply over a long cable from a variable speed drive (VSD) at the surface. The VSD switching generally contributes differential mode as well as common mode electromagnetic interference (EMI) noise that is transmitted to the ESP motor, which may result in a voltage differential between a motor shaft and the motor housing, leading to an induced current path across the motor bearings. The EMI noise also causes discharge through the motor insulation. Further, in certain cases, a magnetic imbalance in the motor may also lead to an induced current path across the motor bearings. In any case, the current path across the motor bearings may lead to mechanical wear (*e.g.*, pitting on the bearing surface) decreasing the lifespan of the bearings, while high-frequency current discharge across the motor insulation may lead to accelerated degradation of the insulation, both of which decrease the lifespan of the ESP motor itself.

[0023] Embodiments of the present disclosure are directed toward solutions that reduce current flow across motor bearings and motor insulation discharge, resulting in enhanced motor bearing, insulation, and ESP motor lifespan. Certain embodiments are directed toward mechanically-based solutions, while other embodiments are directed toward electrically-based solutions, and of course embodiments may employ a combination of mechanically- and electrically-based solutions. It is noted that while a voltage differential between the motor shaft and housing arising from EMI noise may be addressed using either or both mechanically- and electrically-based solutions, electrically-

based solutions may be less effective for addressing a voltage differential arising from a magnetic imbalance in the motor.

[0024] Embodiments directed toward mechanically-based solutions may utilize an electrically conductive brush coupled to the rotor shaft of the motor. In particular, the brush is configured to be biased radially outward and into electrical contact with the motor housing, thereby providing an alternate path for current to flow when a voltage differential may exist between the shaft and housing. Thus, the likelihood of current arcing across motor bearings and discharge through insulation is reduced, which in turn reduces the mechanical wear on the bearings (*e.g.*, pitting on the bearing surface), degradation of the motor insulation, and extends the lifespan of the ESP motor itself.

[0025] The brush may be housed in a recess of the rotor shaft, which may extend either partially or all the way through the rotor shaft. In the latter example, the brush may extend all the way through the rotor shaft as well, or two brushes may be employed, one extending from either side of the rotor shaft. The brush or brushes may be biased radially outward by known biasing elements, such as a spring, or in certain embodiments may be biased outward as a result of centrifugal force that results from the rotation of the rotor shaft. In certain embodiments, an electrically conductive contact ring may be coupled to the housing and positioned relative to the rotor shaft such that the brush or brushes are biased into contact with the contact ring rather than the housing itself. The use of such a contact ring may allow for easier servicing, increased tolerances, and the like.

[0026] Other embodiments of the present disclosure may employ an electrically conductive element (*e.g.*, a brush, a pin, or the like) coupled to a base of the motor that contacts an end surface of the rotor shaft. By so positioning the electrically conductive element, less relative motion exists between the element and the surface of the rotor shaft (relative to a rotating brush contacting the

housing), which may result in increased durability and wear properties. As above, the electrically conductive element may be biased toward and into electrical contact with the end of the rotor shaft, for example by a spring. Also as above, the electrically conductive element coupled to the base of the motor housing and biased into contact with the end of the rotor shaft provides an alternate path for current to flow when a voltage differential may exist between the shaft and housing. Thus, the likelihood of current arcing across motor bearings is reduced, which in turn reduces the mechanical wear on the bearings (*e.g.*, pitting on the bearing surface) and extends the lifespan of the ESP motor itself.

[0027] Certain embodiments may employ an electrically-based solution. In particular, a filter or combination of filters is coupled to or proximate to the motor terminals downhole. The filter or filters are configured to reduce an electromagnetic noise component transmitted to the motor from a topside power drive such as a VSD. Importantly, positioning the filter proximate to the VSD rather than the motor terminals would not sufficiently address the voltage differentials created by EMI noise in the transmitted power signals, as the cables between the VSD and the motor terminals are often several to tens of thousands of feet long, or greater. Cables of such a great length will often include their own leakage path, serving to amplify any remaining EMI noise even after filtering at or proximate to the VSD. Thus, by positioning the filter or filters proximate to the motor terminals themselves, embodiments of the present disclosure reduce or eliminate the amplifying influence that cable length may have on EMI noise.

[0028] Referring now to FIG. 1, an example of an ESP system 100 is shown. The ESP system 100 includes a network 101, a well 103 disposed in a geologic environment, a power supply 105, an ESP 110, a controller 130, a motor controller 150, and a VSD unit 170. The power supply 105

may receive power from a power grid, an onsite generator (*e.g.*, a natural gas driven turbine), or other source. The power supply 105 may supply a voltage, for example, of about 4.16 kV.

[0029] The well 103 includes a wellhead that can include a choke (*e.g.*, a choke valve). For example, the well 103 can include a choke valve to control various operations such as to reduce pressure of a fluid from high pressure in a closed wellbore to atmospheric pressure. Adjustable choke valves can include valves constructed to resist wear due to high velocity, solids-laden fluid flowing by restricting or sealing elements. A wellhead may include one or more sensors such as a temperature sensor, a pressure sensor, a solids sensor, and the like.

[0030] The ESP 110 includes cables 111, a pump 112, gas handling features 113, a pump intake 114, a motor 115 and one or more sensors 116 (*e.g.*, temperature, pressure, current leakage, vibration, etc.). The well 103 may include one or more well sensors 120, for example, such as the commercially available OpticLine™ sensors or WellWatcher BriteBlue™ sensors marketed by Schlumberger Limited (Houston, Tex.). Such sensors are fiber-optic based and can provide for real time sensing of downhole conditions. Measurements of downhole conditions along the length of the well can provide for feedback, for example, to understand the operating mode or health of an ESP. Well sensors may extend thousands of feet into a well (*e.g.*, 4,000 feet or more) and beyond a position of an ESP.

[0031] The controller 130 can include one or more interfaces, for example, for receipt, transmission or receipt and transmission of information with the motor controller 150, a VSD unit 170, the power supply 105 (*e.g.*, a gas fueled turbine generator or a power company), the network 101, equipment in the well 103, equipment in another well, and the like. The controller 130 may also include features of an ESP motor controller and optionally supplant the ESP motor controller 150.

[0032] The motor controller 150 may be a commercially available motor controller such as the UniConn™ motor controller marketed by Schlumberger Limited (Houston, Tex.). The UniConn™ motor controller can connect to a SCADA system, the LiftWatcher™ surveillance system, etc. The UniConn™ motor controller can perform some control and data acquisition tasks for ESPs, surface pumps, or other monitored wells. The UniConn™ motor controller can interface with the Phoenix™ monitoring system, for example, to access pressure, temperature, and vibration data and various protection parameters as well as to provide direct current power to downhole sensors. The UniConn™ motor controller can interface with fixed speed drive (FSD) controllers or a VSD unit, for example, such as the VSD unit 170.

[0033] In accordance with various examples of the present disclosure, the controller 130 may include or be coupled to a processing device 190. Thus, the processing device 190 is able to receive data from ESP sensors 116 and/or well sensors 120. As will be explained in further detail below, the processing device 190 analyzes the data received from the sensors 116 and/or 120 to generate a health status of the ESP 110. The controller 130 and/or the processing device 190 may also monitor surface electrical conditions (*e.g.*, at the output of the drive) to gain knowledge of certain downhole parameters, such as downhole vibrations, which may propagate through changes in induced currents. Thus, a vibration sensor may refer to a downhole gauge or sensor, or surface electronics such as the controller 130 and/or processor 190 that measure downhole conditions through other means, such as change in various monitored electrical parameters. The health status of the ESP 110 may be presented to a user through a display device (not shown) coupled to the processing device 190, through a user device (not shown) coupled to the network 101, or other similar manners.

[0034] FIG. 2 shows an exemplary motor 200 in accordance with embodiments of the present disclosure. The motor 200 comprises a housing 202, which may be referred to alternately as a stator, and a rotor shaft 204 within the housing 202. The rotor shaft includes rotor lamination 206 that are stacked to make up the rotor core and several rotor radial bearings 208. A current path is demonstrated by the arrows through the rotor shaft 204 and the rotor radial bearings 208. As explained above, voltage differentials may exist between the rotor shaft 204 and the housing 202, and a current may be induced across the rotor bearings 208 (*e.g.*, arcing may occur). This results in mechanical wear such as pitting to the surface of the bearings 208, reducing the lifespan of the motor 200.

[0035] FIG. 3a shows a cutaway view of a motor 300 in accordance with embodiments of the present disclosure. The motor 300 comprises a housing 302 and a rotor shaft 304 similar to those described above. Additionally, the rotor shaft 304 comprises a brush 306 positioned in a recess of the rotor shaft 304 and that is biased outward and into electrical contact with the housing 302, providing a favorable current path rather than across the radial bearings 208. In FIG. 3a, a contact ring 308 is shown as coupled to the housing 302 and positioned in a way such that the brush 306 makes contact with the contact ring 308 rather than the housing 302. Although not strictly required, the use of such a contact ring 308 may allow for simplified servicing of a part that may wear over time.

[0036] FIG. 3b shows a cross-sectional view of the motor 300 of FIG. 3a. In particular, it can be seen that the example of FIG. 3b includes two brushes 306a, 306b on either side of the rotor shaft 304. Further, a biasing element 310 (*e.g.*, a spring or the like) may be disposed between the two brushes 306a, 306b to urge each brush 306a, 306b radially outward and into electrical contact with the housing 302 or the contact ring 308, which is coupled to and electrically conductive with the

housing 302. In other embodiments, the brushes 306a, 306b may be biased outward by the centrifugal force that results from rotation of the rotor shaft 304, thus obviating the need for an additional mechanical biasing element.

[0037] Turning to FIG. 4, an alternate embodiment is shown in which an electrically conductive element 404 is coupled to a base 402 of the motor housing 302. The electrically conductive element 404 is biased toward an end surface of the rotor shaft 304, thus providing electrical coupling between the shaft 304 and the housing 302. A biasing element 406 may be disposed in the base 402 to urge the electrically conductive element 404 into contact with the rotor shaft 304. The electrically conductive element 404 may comprise a pin as shown, a brush, or other type of element.

[0038] FIG. 5 shows an ESP string 500 in accordance with embodiments of the present disclosure. An AC power cable 502 transmits power from the surface that, as explained, may likely include an EMI noise component. A filter 504, which may be passive, active, or a combination of filters is proximate to the ESP motor 506. The filter 504 reduces or eliminates the EMI noise component of the transmitted power signal from a topside VSD, which is one of the primary causes of an induced voltage between the shaft 304 and the housing 302, leading to the current problems described above. The depicted example is that of a bottom intake ESP configuration, and thus also includes a bottom intake pump 510 and sealing assembly 512 along with a seal and pump discharge 508. Of course, embodiments of the present disclosure may be similarly applied for a top intake ESP as well.

[0039] Turning to FIGS. 6a and 6b, an exemplary passive filter 600 and active filter 650 are shown coupled to the motor terminals of the motor 200. In particular, the passive filter 600 receives 3-phase power 602 from a topside VSD (not shown) and employs a differential mode filter (*e.g.*,

an LC or LCL filter) 604, a common mode filter 606, or a combination thereof to reduce the EMI noise component of the received power signal. The active filter 650 similarly receives 3-phase power 602 from a topside VSD (not shown). A three-phase, high-bandwidth line-to-ground voltage measurement 652 is performed, and the results of the block 652 are provided to a second block 654, which subtracts a fundamental voltage value and applies a reverse sign to the result. The result of the second block 654 is provided to a second stage of an AC-DC-AC conversion network 656, the result of which is a filtered signal being provided to the motor 200.

[0040] Regardless of the type of filter 600, 650, the EMI noise component of the transmitted power signal from a topside VSD is reduced or eliminated, reducing current flow across the motor bearings 208 and motor insulation discharge, thereby extending their effectiveness and the lifespan of the motor 200 itself. As noted above, leveraging a filter 600, 650 proximate to the motor 200 addresses EMI noise introduced by a VSD; however, the filters 600, 650 do not address magnetic imbalances at the motor 200 itself that give rise to voltage differentials between the shaft 304 and housing 302. Thus, certain embodiments of the present disclosure may utilize solely mechanically-based solutions described above, solely electrically-based solutions, or combinations thereof to further protect against the damage caused by current flow across motor bearings and the EMI filters eliminate discharge through the motor insulation.

[0041] As explained above, the differential mode filter 604 is an LC or LCL filter operating in a downhole environment proximate to terminals of the motor 200. The common mode filter 604, in certain embodiments, comprises a 3-phase common mode inductor having a toroidal core and 3-phase winding wound around it as shown in FIG. 7a. The common mode filter 604 creates a high impedance for high-frequency common mode noise generated by a fast-switching pulse-width modulated drive, and thus reduces the risk of motor shaft and bearing currents due to the exemplary

flux linkage physics depicted in FIG. 7b. The common mode filter 604 also reduces a common mode component of the cable capacitive discharge currents, which will flow through the point of ground fault in the event a ground fault occurs in the motor 200. This reduces damage to the motor insulation system arising from the ground fault occurrence and thus results in the motor 200 being able to operate for additional time with one phase shorted to ground. One skilled in the art should appreciate that capacitors may be used in addition to inductors, if needed, for example to adjust filter characteristics for certain various application considerations.

[0042] Although only a few example embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from the electrical connector assembly. Features shown in individual embodiments referred to above may be used together in combinations other than those which have been shown and described specifically. Accordingly, all such modifications are intended to be included within the scope of this disclosure as defined in the following claims.

[0043] The embodiments described herein are examples only and are not limiting. Many variations and modifications of the systems, apparatus, and processes described herein are possible and are within the scope of the disclosure. Accordingly, the scope of protection is not limited to the embodiments described herein, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims.

CLAIMS

What is claimed is:

1. A downhole motor, comprising:
a housing;
a rotor shaft configured to rotate within the housing; and
an electrically conductive brush coupled to the rotor shaft and configured to be biased radially outward and into electrical contact with the housing.
2. The downhole motor of claim 1 wherein the rotor shaft comprises a radial recess configured to contain at least a portion of the brush.
3. The downhole motor of claim 2 further comprising a second electrically conductive brush coupled to the rotor shaft and configured to be biased radially outward and into electrical contact with the housing, wherein the recess comprises a radial throughbore, each end of the throughbore configured to contain at least a portion of one of the electrically conductive brushes.
4. The downhole motor of claim 1 further comprising a spring coupled to a portion of the rotor shaft and configured to bias the brush radially outward.
5. The downhole motor of claim 1 wherein the brush is configured to be biased radially outward in response to a centrifugal force that results from rotation of the rotor shaft.

6. The downhole motor of claim 1 further comprising an electrically conductive contact ring coupled to the housing and positioned relative to the rotor shaft such that the brush is biased radially outward into contact with the contact ring.
7. The downhole motor of claim 1 further comprising one or more rotor bearings, wherein as a result of a voltage difference between the housing and the rotor shaft, a current flows between the housing and the rotor shaft through the electrically conductive brush and no current flows through the rotor bearings.
8. The downhole motor of claim 1 further comprising:
motor terminals configured to receive power from a multi-phase power drive by way of a plurality of cables, whereby the multi-phase power drive introduces an electromagnetic noise component that is transmitted to the downhole motor by way of the plurality of cables; and
a filter proximate and coupled to the motor terminals and configured to reduce the electromagnetic noise component transmitted to the downhole motor.
9. A downhole motor, comprising:
a housing comprising a base;
a rotor shaft configured to rotate within the housing, the rotor shaft comprising an end surface proximate to the base; and
an electrically conductive element coupled to the base and configured to be biased toward and into electrical contact with the end surface of the rotor shaft.

10. The downhole motor of claim 9 wherein the electrically conductive element comprises a brush or a pin.
11. The downhole motor of claim 9 further comprising a spring coupled to the base and configured to bias the electrically conductive element toward the end surface of the rotor shaft.
12. The downhole motor of claim 9 further comprising one or more rotor bearings, wherein as a result of a voltage difference between the housing and the rotor shaft, a current flows between the housing and the rotor shaft through the electrically conductive element and no current flows through the rotor bearings.
13. The downhole motor of claim 9 further comprising:
motor terminals configured to receive power from a multi-phase power drive by way of a plurality of cables, whereby the multi-phase power drive introduces an electromagnetic noise component that is transmitted to the downhole motor by way of the plurality of cables; and
a filter proximate and coupled to the motor terminals and configured to reduce the electromagnetic noise component transmitted to the downhole motor.
14. A system, comprising:
a downhole motor comprising motor terminals and configured to receive power from a multi-phase power drive by way of a plurality of cables, whereby the multi-phase

power drive introduces an electromagnetic noise component that is transmitted to the downhole motor by way of the plurality of cables;
a filter proximate and coupled to the motor terminals and configured to reduce the electromagnetic noise component transmitted to the downhole motor.

15. The system of claim 14 wherein the filter comprises a passive filter.
16. The system of claim 14 wherein the filter comprises an active filter.

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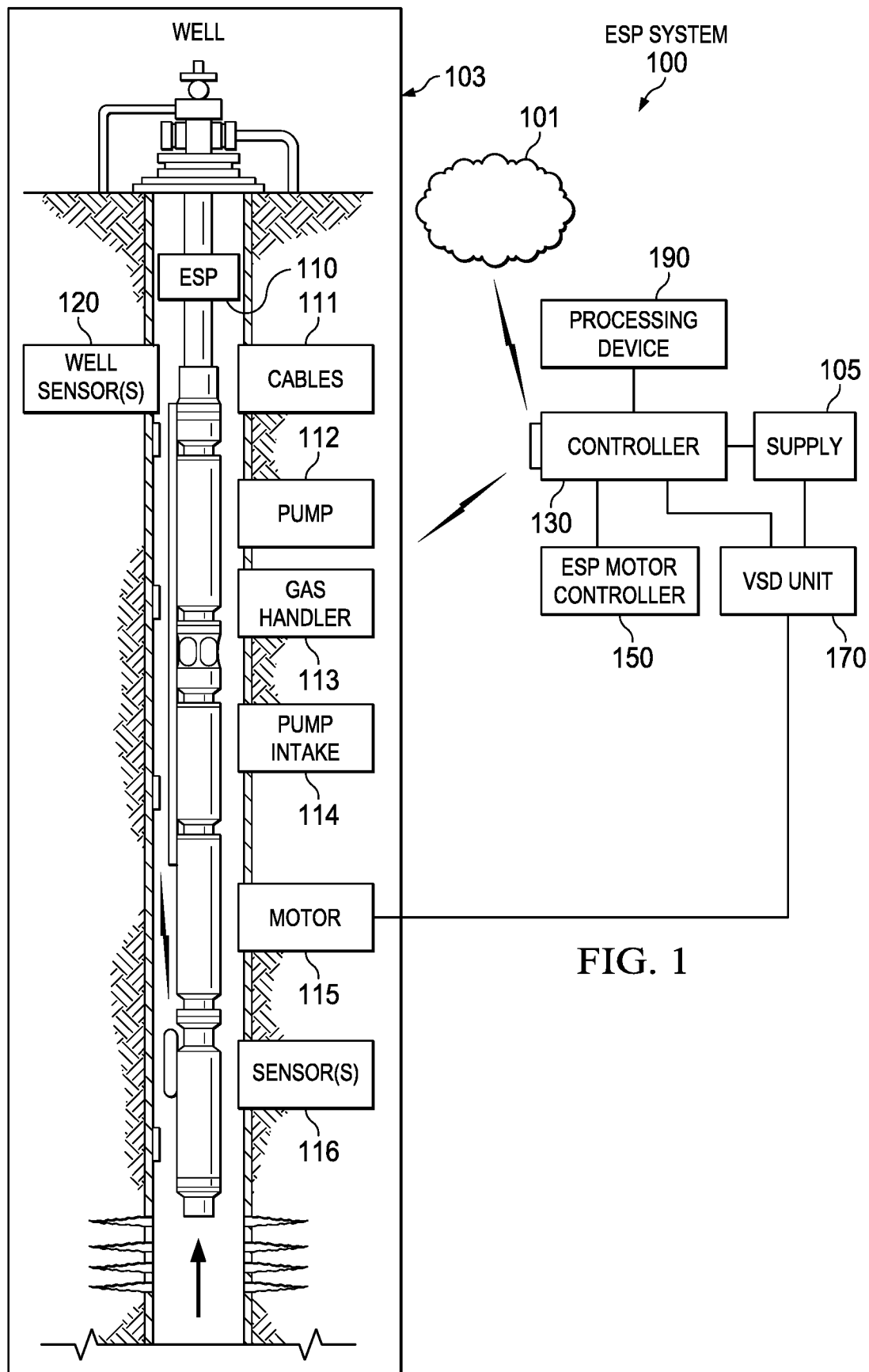


FIG. 1

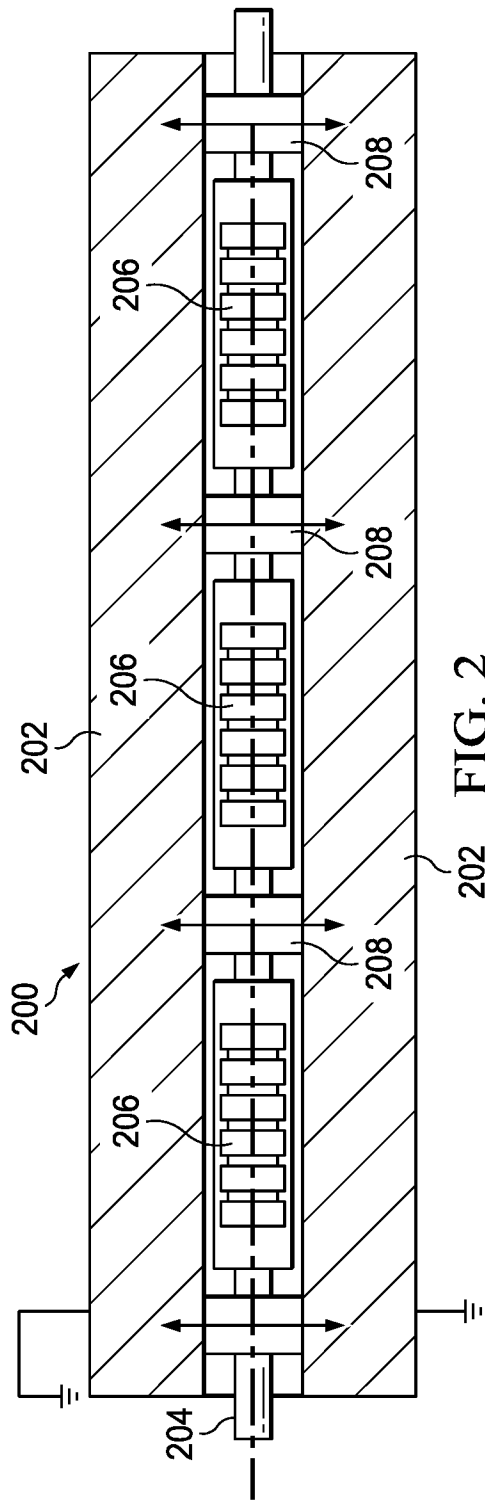


FIG. 2

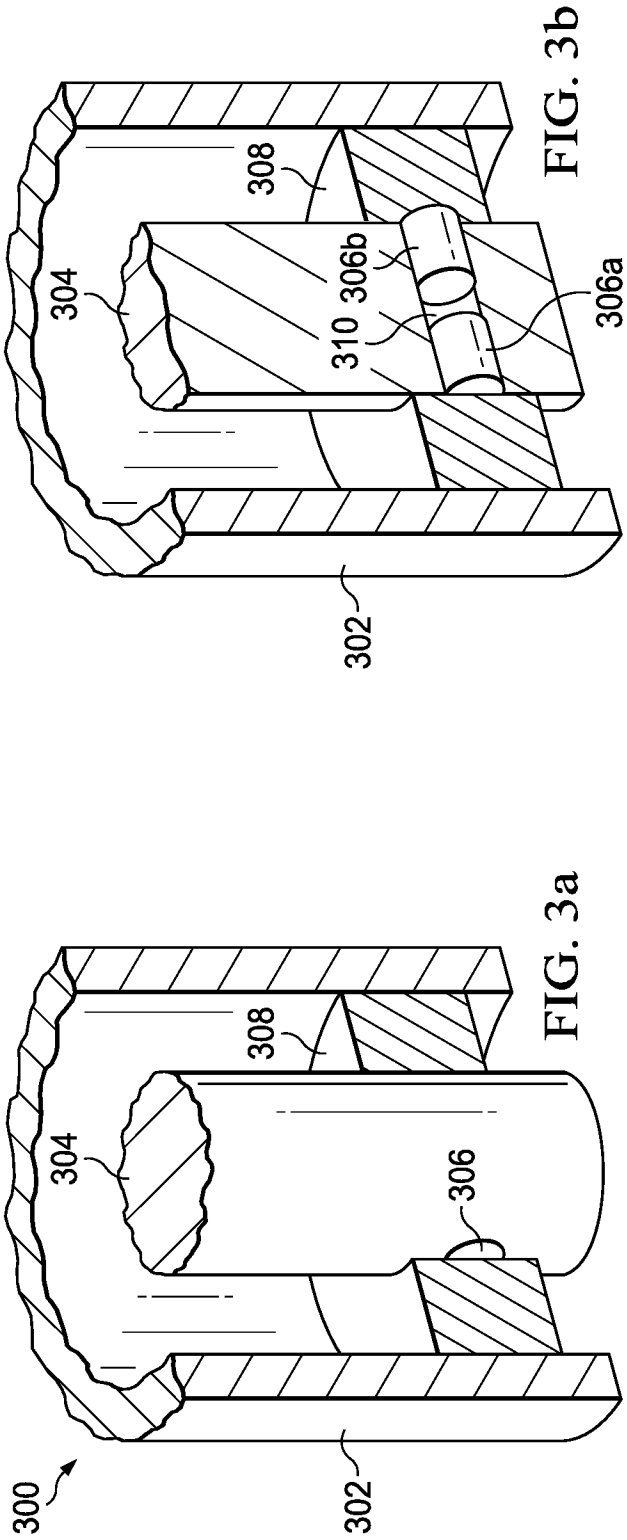


FIG. 3a

FIG. 3b

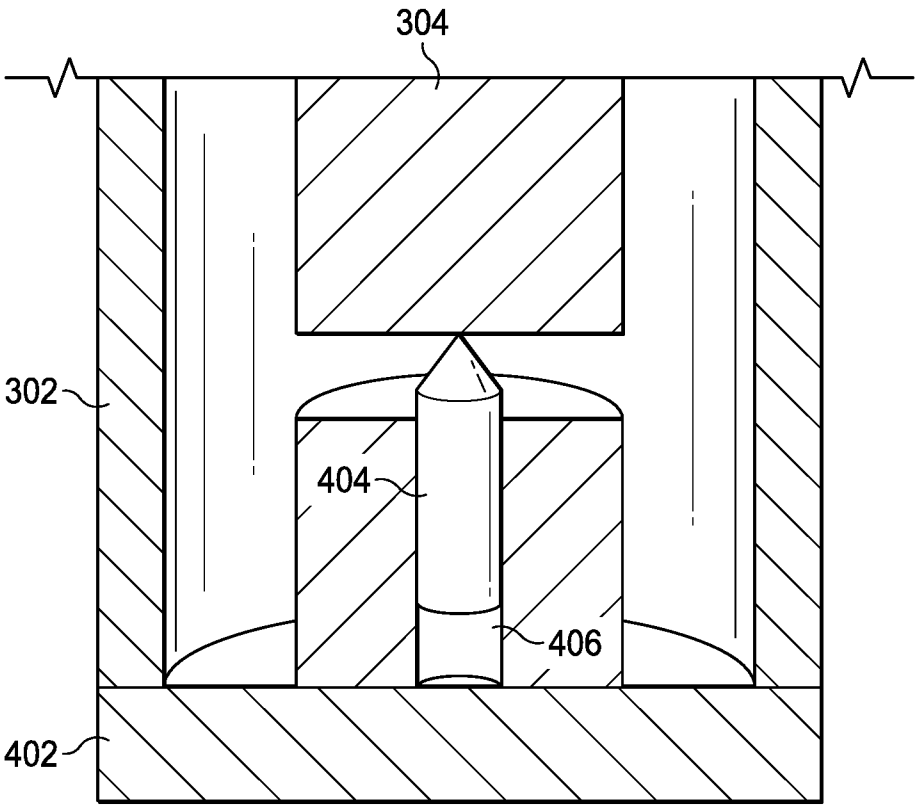


FIG. 4

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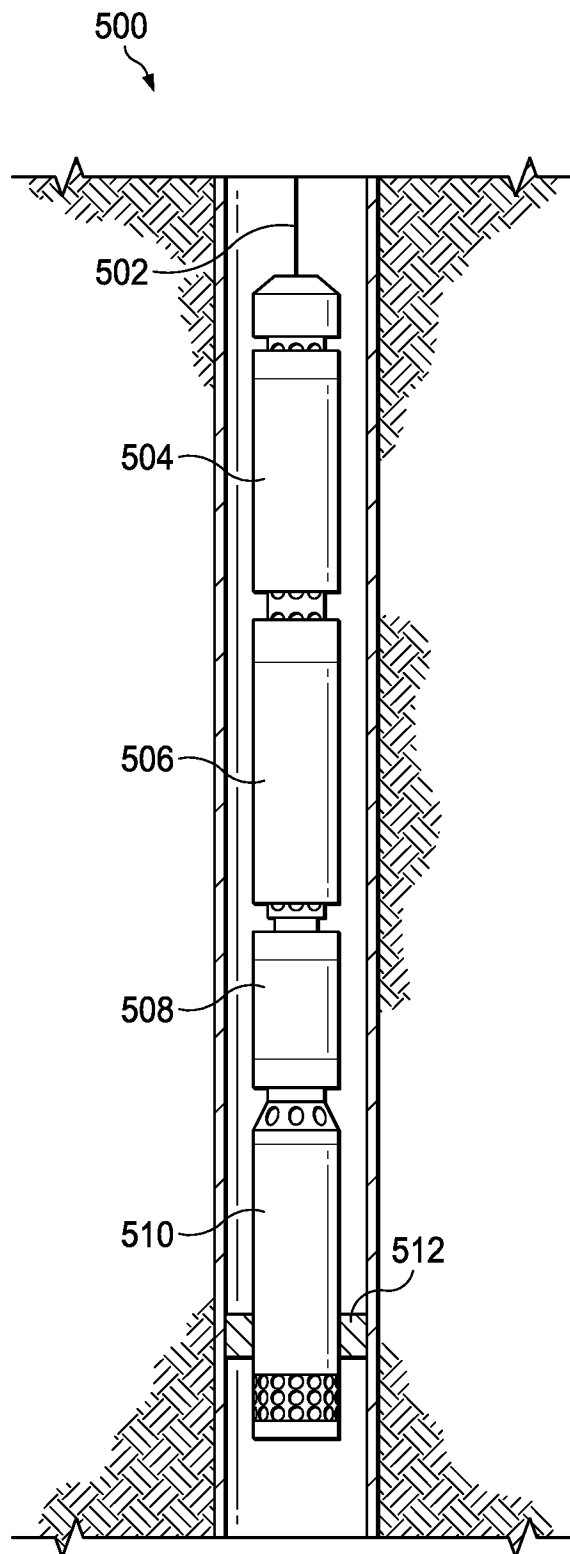


FIG. 5

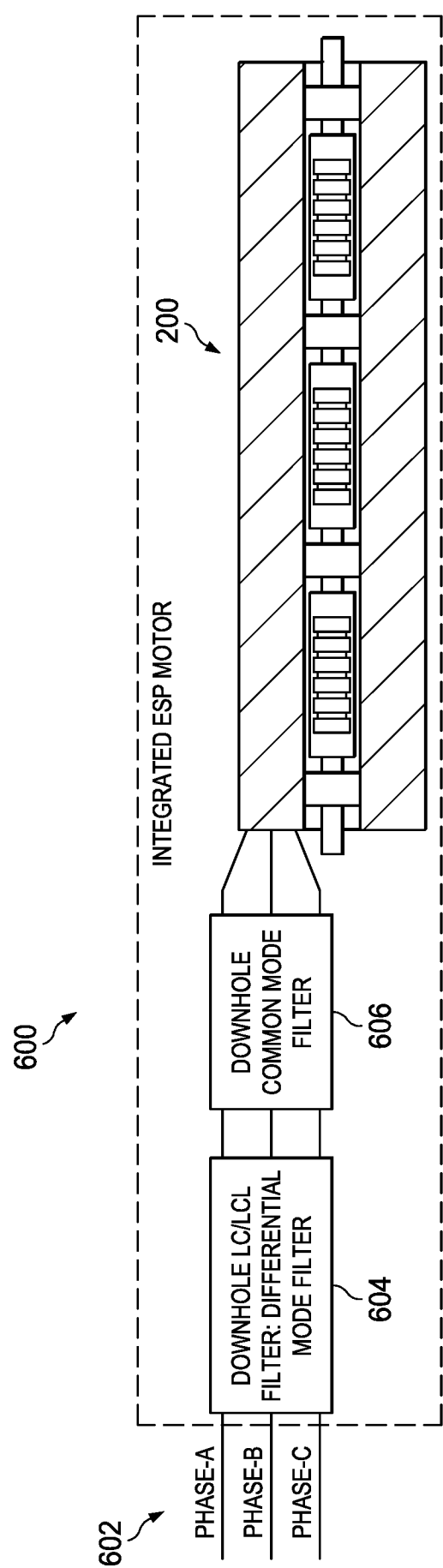


FIG. 6a

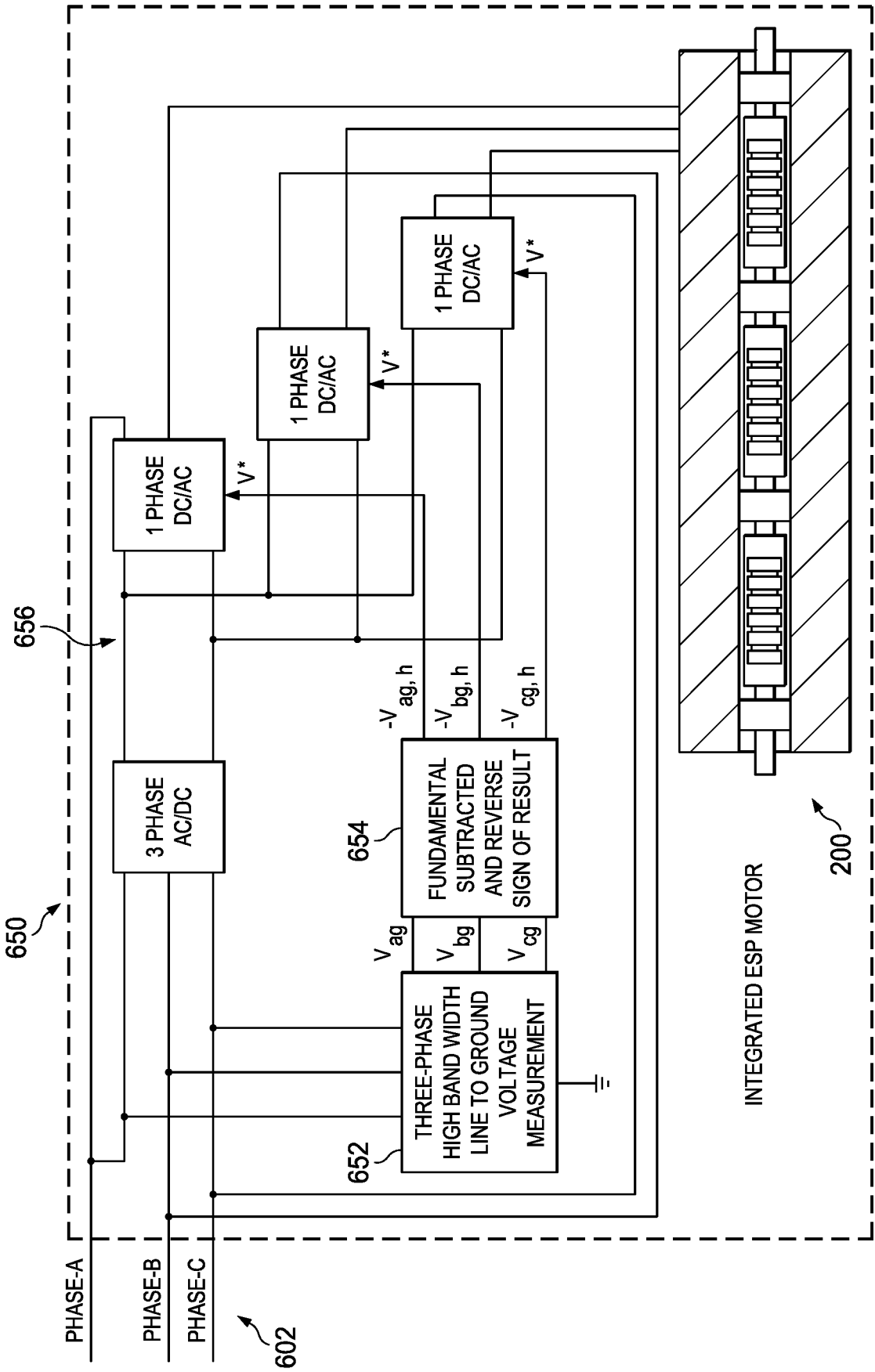


FIG. 6b

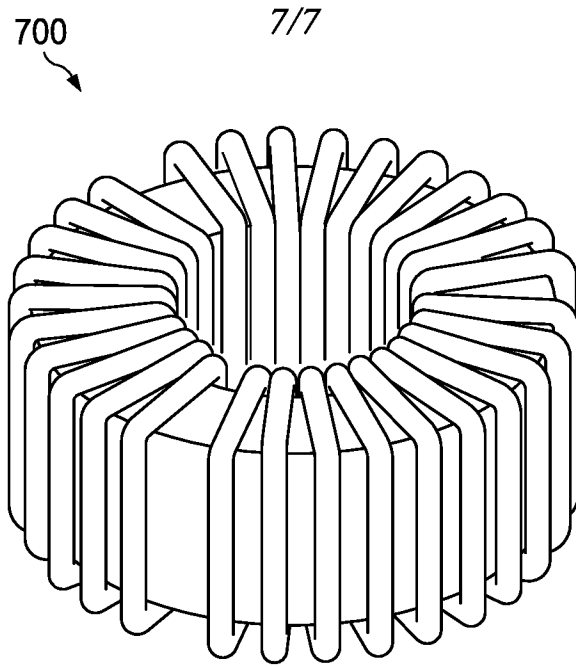


FIG. 7a

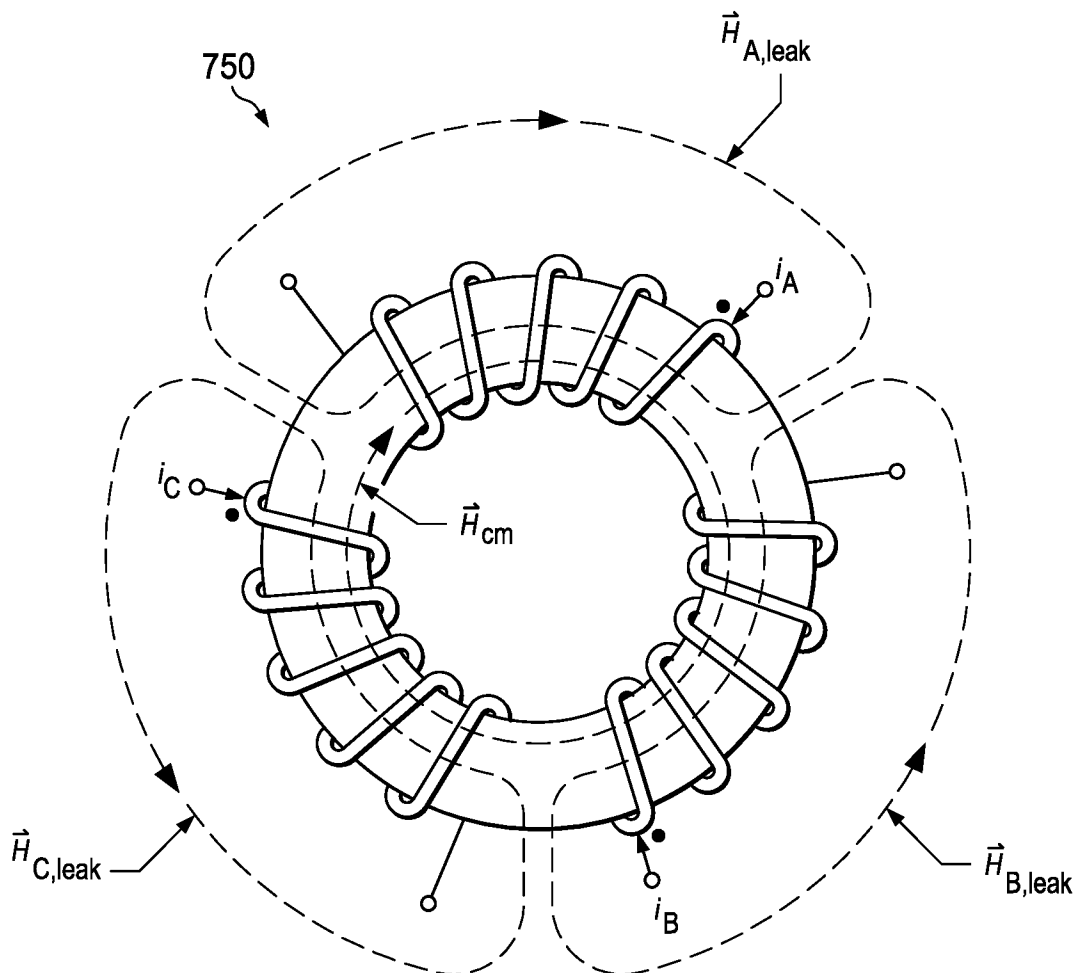


FIG. 7b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/036156**A. CLASSIFICATION OF SUBJECT MATTER****F04B 47/06(2006.01)i, E21B 43/12(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F04B 47/06; F04B 35/04; H05F 3/02; H05F 3/00; F16C 41/04; H02K 11/00; H01R 39/12; E21B 43/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: downhole motor, shaft, bearing, brush, pin, centrifugal force, voltage difference, current, filter, and electromagnetic noise

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5988996 A (BROOKBANK et al.) 23 November 1999 See column 1, line 66 - column 2, line 67 and figure 2.	1-16
Y	US 4515417 A (SHIRAISHI, AKIYOSHI) 07 May 1985 See column 2, lines 48-63 and figure 5.	1-13
Y	US 2004-0189115 A1 (PREISINGER et al.) 30 September 2004 See abstract, paragraph [0014], claim 1, and figure.	8, 13-16
A	US 2011-0193446 A1 (ORLOWSKI et al.) 11 August 2011 See paragraphs [0060]-[0064] and figure 2.	1-16
A	US 2011-0216466 A1 (OH et al.) 08 September 2011 See paragraphs [0024]-[0031] and figures 1-3.	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

07 March 2017 (07.03.2017)

Date of mailing of the international search report

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Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/036156

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