

SYSTEM AND METHOD FOR AN AC POWERED DOWNHOLE GAUGE**BACKGROUND**5 **1. Field of Invention**

[0001] The present invention is directed, in general, to borehole production power systems and, more specifically, to powering downhole measurement and control mechanisms using alternating current power over the three phase power cable.

2. **Description of Prior Art**

10 [0002] Downhole electrical submersible pump (ESP) instrumentation systems are typically powered by impressing a direct current (DC) voltage relative to ground on all three phases of the three phase power cable carrying power to the pump motor. As a result, the normally floating phases of the three phase power system no longer float but are instead maintained at this voltage (on average).

15 [0003] The impressed DC voltage is used to power measurement devices within the borehole and, in most cases, to transmit data back to the surface. However, these direct current systems limit high voltage insulation testing of the three phase cable, and become inoperable if any phase of the three phase power system shorts to ground.

[0004] There is, therefore, a need in the art for an improved system for powering
20 downhole instrumentation over a three phase power cable carrying power to a pump motor.

SUMMARY OF INVENTION

[0005] To address the above-discussed deficiencies of the prior art, it is a primary object of the present invention to provide, for use in a borehole production system, AC instrument power for borehole instruments that is transmitted on all three phases of a power cable concurrently carrying three phase motor power, the instrument power transmitted at a multiple of the motor power frequency and having a corresponding fraction of the motor power voltage. The instrument power is received via a capacitive coupling sufficient to withstand high-voltage cable insulation testing. The phase-to-neutral motor power provides approximately the same power level to the borehole instruments if a phase shorts to ground.

[0006] The foregoing has outlined rather broadly the features and technical advantages of the present invention so that those skilled in the art may better understand the detailed description of the invention that follows. Additional features and advantages of the invention will be described hereinafter that form the subject of the claims of the invention. Those skilled in the art will appreciate that they may readily use the conception and the specific embodiment disclosed as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. Those skilled in the art will also realize that such equivalent constructions do not depart from the spirit and scope of the invention in its broadest form.

BRIEF DESCRIPTION OF DRAWINGS

[0007] Some of the features and benefits of the present invention having been stated, others will become apparent as the description proceeds when taken in conjunction with the accompanying drawings, in which:

5 [0008] FIG. 1 depicts a borehole production system including a borehole measurement/control device and pump motor power system according to one embodiment of the present invention;

[0009] FIG. 2 depicts in greater detail the gauge subassembly for use within a borehole production system according to one embodiment of the present invention; and

10 [0010] FIG. 3 graphically illustrates the relationship between instrument and motor power on a three phase cable within a borehole production system according to one embodiment of the present invention.

[0011] While the invention will be described in connection with the preferred embodiments, it will be understood that it is not intended to limit the invention to that
15 embodiment. On the contrary, it is intended to cover all alternatives, modifications, and equivalents, as may be included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF INVENTION

[0012] The present invention will now be described more fully hereinafter with reference to the accompanying drawings in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should
5 not be construed as limited to the illustrated embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

[0013] FIGURE 1 depicts a borehole production system including a borehole
10 measurement/control device and pump motor power system according to one embodiment of the present invention. Borehole production system 100 in the exemplary embodiment includes an electrical submersible pump and motor subassembly 101 lowered within a borehole 102 by means of production tubing 103.

[0014] The motor portion of pump and motor subassembly 101 is powered by three
15 phase power transmitted from the surface over a three phase cable 104. A power source 105 provides the three phase power transmitted to the motor. Those skilled in the art will recognize that power source 105 may comprise a variety of components, such as, for example, a generator or connection to a power distribution grid, a converter and/or inverter, and/or a variable frequency drive (VFD) or variable speed drive (VSD).

20 [0015] Power source 105 in the present invention also includes a subassembly 106 for generating single phase alternating current (AC) power to be transmitted over three phase cable 104 for use in powering measurement and/or control devices within a gauge subassembly 107 located within the borehole 102. The single phase power for

the measurement and/or control devices differs in frequency and peak amplitude from the three phase power for the pump motor, as described in further detail below.

[0016] Borehole production system 100 includes at least one gauge subassembly 107 disposed within the borehole. Gauge subassembly 107, described in further detail below, measures such characteristics as temperature, pressure, cut, flow rate, or other parameters of the fluid being pumped. Alternatively, gauge subassembly 107 may measure intake pressure, temperature or flow rate, outlet pressure, temperature or flow rate, revolutions per minute, or other operating parameters of the motor/pump subassembly 101. In still further embodiments, gauge subassembly 107 may include, with or without any measurement devices, control mechanisms for opening or closing valves or for operating other electrical or mechanical devices.

[0017] While only one gauge subassembly 107 is depicted in FIGURE 1, those skilled in the art will recognize that any number of such subassemblies may be employed, and at various locations along the borehole 102 such as below the motor, between the motor and pump, above the pump and/or at the seal, proximate to a packer, at the wellhead (for a subsea well), etc.

[0018] In the exemplary embodiment, gauge subassembly 107 is connected to the neutral point termination of a Y-connected three phase motor within the motor/pump subassembly 101. Alternatively, however, the gauge subassembly (or each gauge subassembly, in the case of a borehole production system including multiple such subassemblies) may be connected to one or more conductors within three phase power cable 104, at any location along borehole 102.

[0019] FIGURE 2 depicts in greater detail the gauge subassembly for use within a borehole production system according to one embodiment of the present invention.

Gauge subassembly 107 includes a capacitor 200 connected to the motor neutral point or to another appropriately formed Y-point (formed from inductors, capacitors or both) coupled to the three phase power cable 104. Capacitor 200 is appropriately sized to transfer instrument power from the three phase power cable 104, and is rated at a sufficiently high voltage, to allow high voltage testing (megging) of the insulation for the three power cable 104 and other downhole equipment.

[0020] Capacitor 200 is coupled by a transformer 201 to a measurement and/or control device 202. The power passed through capacitor 200 and transformer 201 is employed to drive electrical components within the measurement and/or control device 202.

[0021] FIGURE 3 graphically illustrates the relationship between instrument and motor power on a three phase cable within a borehole production system according to one embodiment of the present invention. The signals depicted illustrate power impressed on the three phase power cable 104. In an exemplary embodiment, the individual conductors of three phase power cable 104 are each driven by one phase A, B or C of the three phase power signal 300 (collectively signals 300A, 300B and 300C). All three phases are also driven by an AC voltage 301 with respect to ground, which is employed as the instrument power for measurement/control device(s) 202 within gauge subassembly 107. Although shown without any direct current offset in the exemplary embodiment, the power on the three phase power cable 104 may also have a ground-referenced direct current component, in which case the instrumentation voltage 301 would be offset from neutral.

[0022] The instrument power 301 is set at a voltage that is on the order of one-tenth (a factor of 10 less than) the voltage of the motor power 300 transmitted on the three

phase power cable 104, and with a frequency that is on the order of ten times higher than the frequency of the motor power 300 (illustrated in FIGURE 3 by the period of the half cycles for the respective signals 300 and 301). For example, instrument power 301 may be approximately 80-100 volts (V) transmitted at 600 Hertz (Hz) while motor
5 power is 1,000 to 2,500 V (peak, up to 4,160 volts phase-to-phase) transmitted at 60 Hz.

[0023] As described above, the gauge subassembly is preferably connected to a Y-point coupled to three phase power cable 104. At such a Y-point in a balanced system (with no phase shorted to ground), only the AC instrument power 301 appears at the Y-
10 point, together with any DC offset. When a phase shorts to ground, however, the cumulative downhole motor phase-to-neutral power for the remaining two phases (or single phase, if two phases short to ground) appears at the Y-point. In such an event, the downhole instrumentation 202 is able to use the motor power voltage for power in lieu of the normal instrument power 301. The higher voltage but reduced frequency of
15 the downhole motor power couples into the instrumentation 202 at relatively the same power level, since the impedance of capacitive coupling 200 is inversely proportional to frequency and the frequencies and voltages of motor power 300 and instrument power 301 were selected to be inversely related as described above. Such a system may also be used where the voltage of motor power 300 is much lower or higher than
20 the exemplary numbers listed above by simply adjusting the frequency and voltage of the instrument power 301 with which gauge 107 is designed to operate.

[0024] In one embodiment of the present invention, the inductance of transformer 201 may be selected to resonate with the capacitor 200 at the frequency of the instrument power 301, providing a low impedance path for the instrument power and a

higher impedance path for the motor power (when a phase is grounded and the motor power appears at the Y-point).

[0025] The above-described embodiments disregard data transfer over three phase power cable 104. However, one or more signaling units 110 may be separately coupled to power cable 104 in accordance with the known art to provide modulation of a DC bias or offset on power cable 104 or by superimposition of a radio frequency (RF) signal in accordance with the known art. Such signaling unit(s) 110 may be communicably coupled to gauge assembly 107 separately from the common connection to power cable 104, providing instrumentation 202 with alternate paths for receiving power and signaling.

[0026] An alternative embodiment of the present invention when the AC power system is floating involves the transfer of data from the surface downhole, from the borehole to the surface, or both by modulation of the AC current demand by a controller (not shown) in the downhole instrumentation 202. The downhole information may thereby be transmitted to the surface as a linear load change proportional to the AC signal, or as discrete levels transferring encoded data. When encoded data is transferred, the AC coupling system allows a much higher data rate than DC powered data signaling systems since the coupling filter time constants are much shorter. Using two or more discrete levels will further enhance the data rate since each data sample will be shorter. Data may be transferred from a controller 108 at the surface to downhole instrumentation 202 (concurrently with, i.e. bi-directionally, or during separate time periods for data transfer from the borehole to the surface) by shifting the frequency of instrument power 301 by a predetermined deviation, or by

briefly interrupting the power signal 301. These techniques allow data to be transferred using the AC instrument power signal 301 as long as the power system is floating.

[0027] The present invention provides power from the surface to downhole instrumentation within a borehole over a three phase power cable, either separately
5 from or concurrently with the three phase power for a downhole motor, in a manner tolerating shorting of a conductor within the three phase power cable to ground and/or high voltage insulation testing.

[0028] It is important to note that while embodiments of the present invention have been described in the context of a fully functional system and method embodying the
10 invention, those skilled in the art will appreciate that the mechanism of the present invention and/or aspects thereof are capable of being distributed in the form of a computer readable medium of instructions in a variety of forms for execution on a processor, processors, or the like, and that the present invention applies equally regardless of the particular type of signal bearing media used to actually carry out the
15 distribution. Examples of computer readable media include but are not limited to: nonvolatile, hard-coded type media such as read only memories (ROMs), CD-ROMs, and DVD-ROMs, or erasable, electrically programmable read only memories (EEPROMs), recordable type media such as floppy disks, hard disk drives, CD-R/RWs, DVD-RAMs, DVD-R/RWs, DVD+R/RWs, flash drives, and other newer types of
20 memories, and transmission type media such as digital and analog communication links. For example, such media can include both operating instructions and/or instructions related to the system and the method steps described above.

[0029] It is to be understood that the invention is not limited to the exact details of construction, operation, exact materials, or embodiments shown and described, as

modifications and equivalents will be apparent to one skilled in the art. In the drawings and specification, there have been disclosed illustrative embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation. Accordingly, the invention is therefore

5 to be limited only by the scope of the appended claims.

CLAIMS

WHAT IS CLAIMED IS:

- 5 1. A borehole instrument power system comprising:
- a three phase power cable extending from a surface location into a borehole, the three phase power cable capable of carrying three phase motor power of voltage and frequency;
- a power source coupled to the three phase power cable, the power source
- 10 producing alternating current instrument power for transmission on all three conductors of the three phase power cable; and
- an instrument capacitively coupled to the three phase power cable to receive the alternating current instrument power over the three phase cable, wherein the alternating current instrument power has a voltage that is less than the three phase motor power
- 15 voltage and a frequency that is more than the three phase motor power frequency.
2. The borehole instrument power system according to claim 1, wherein the capacitive coupling of the instrument to the three phase power cable can withstand high voltage testing of the three phase power cable insulation.
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3. The borehole instrument power system according to claim 1, wherein the instrument is also inductively coupled to the three phase power cable, the inductive and capacitive couplings selected to provide a low impedance path for the alternating current instrument power and a high impedance path for the three phase motor power.

4. The borehole instrument power system according to claim 1, further comprising one or more controllers to bi-directionally transmit data over the three phase power cable.

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5. The borehole instrument power system according to claim 4, wherein the data is bi-directionally transmitted over the three phase power cable by interrupting the alternating current instrument power, shifting a frequency of the alternating current instrument power or modulating the alternating current instrument power.

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6. The borehole instrument power system according to claim 1, wherein the instrument further comprises:

at least one gauge subassembly for measuring an operating characteristic or controlling a device; and

15 a signaling unit communicatively coupled to the at least one gauge subassembly which transmitting data on the three phase power cable.

7. The borehole instrument power system according to claim 1, wherein the at least one gauge subassembly is connected to a Y-point coupled to the three phase
20 power cable.

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8. A method of powering a borehole instrument comprising:

providing a three phase power cable from a surface location into a borehole, the three phase power cable capable of carrying three phase motor power of voltage and
5 frequency;

coupling a power source to the three phase power cable, the power source producing alternating current instrument power for transmission on all three conductors of the three phase power cable; and

capacitively coupling an instrument to the three phase power cable to receive
10 the alternating current instrument power over the three phase cable, wherein the alternating current instrument power has a voltage that is less than the three phase motor power voltage and a frequency that is more than the three phase motor power frequency.

15 9. The method according to claim 8, wherein the capacitive coupling of the instrument to the three phase power cable can withstand high voltage testing of the three phase power cable insulation.

10. The method according to claim 8, wherein the instrument is also inductively
20 coupled to the three phase power cable, the inductive and capacitive couplings selected to provide a low impedance path for the alternating current instrument power and a high impedance path for the three phase motor power.

11. The method according to claim 8, further comprising bi-directionally transmitting data on the three phase power cable between the surface location and the instrument.

5 12. The method according to claim 8, wherein the bi-directional transmission is achieve through modulating the alternating current instrument power, interrupting a frequency of the alternating current instrument power or shifting a frequency of the alternating current instrument power.

10 13. The method according to claim 8, further comprising:
providing at least one gauge subassembly for measuring an operating characteristic or controlling a device; and
communicatively coupling a signaling unit to the at least one gauge subassembly for transmitting data on the three phase power cable.

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14. The method according to claim 8, wherein the at least one gauge subassembly is connected to a Y-point coupled to the three phase power cable.

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15. A borehole system comprising:

a three phase power cable extending from the surface location into the borehole,
5 the three phase power cable capable of carrying three phase motor power of voltage and frequency;

a power source coupled to the three phase power cable, the power source producing alternating current instrument power for transmission on all three conductors of the three phase power cable;

10 an electrical submersible pump coupled to the three phase power cable, the electrical submersible pump including a motor receiving the three phase motor power from the three phase power cable; and

an instrument capacitively coupled to the three phase power cable to receive the alternating current instrument power over the three phase cable, wherein the alternating
15 current instrument power has a voltage that is approximately a fraction $1/N$ of the three phase motor power voltage and a frequency that is approximately a multiple N of the three phase motor power frequency.

16. The borehole instrument power system according to claim 15, wherein the
20 capacitive coupling of the instrument to the three phase power cable can withstand high voltage testing of the three phase power cable insulation.

17. The borehole instrument power system according to claim 15, wherein the instrument is also inductively coupled to the three phase power cable, the inductive and

capacitive couplings selected to provide a low impedance path for the alternating current instrument power and a high impedance path for the three phase motor power.

18. The borehole instrument power system according to claim 17, further comprising:

- 5 a controller within the instrument modulating AC current drawn by the instrument to transmit data on the three phase power cable to the surface location; and
- a second coupled to the three phase power cable and transmitting data over the three phase power cable to the instrument either by temporarily shifting a frequency of the alternating current instrument power or by temporarily interrupting the alternating
- 10 current instrument power.