(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 290 780 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
09.09.2009 Bulletin 2009/37

(21) Application number: **01935337.4**

(22) Date of filing: **11.05.2001**

(51) Int Cl.:
H02M 7/5387 *(2007.01)* ***F04D 13/08*** *(2006.01)*

(86) International application number:
PCT/US2001/015249

(87) International publication number:
WO 2001/089068 (22.11.2001 Gazette 2001/47)

(54) **METHOD FOR BOOSTING THE OUTPUT VOLTAGE OF A VARIABLE FREQUENCY DRIVE**

VERFAHREN ZUR ERHÖHUNG DER AUSGANGSSPANNUNG EINES FREQUENZVERÄNDERBAREN ANTRIEBES

PROCEDE PERMETTANT D'ELEVER LA TENSION DE SORTIE D'UN MECANISME D'ENTRAINEMENT A FREQUENCE VARIABLE

(84) Designated Contracting States:
CH DE FI LI

(30) Priority: **12.05.2000 US 203792 P**
17.05.2000 US 204818 P

(43) Date of publication of application:
12.03.2003 Bulletin 2003/11

(73) Proprietor: **BAKER HUGHES INCORPORATED**
Houston, TX 77019-2118 (US)

(72) Inventors:
- **RIDER, Jerald**
  Catoosa, OK 74015 (US)
- **LAYTON, James, E.**
  Chelsea, OK 74016 (US)
- **LEUTHEN, John, M.**
  Claremore, OK 74016 (US)
- **KNOX, Dick, L.**
  Claremore, OK 74016 (US)

(74) Representative: **Finck, Dieter et al**
v. Füner Ebbinghaus Finck Hano
Mariahilfplatz 2 - 3
81541 München (DE)

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Description

[0001] The present invention relates to an electrical power system for a motor within a wellbore for use in a downhole power system, as well as to a method of powering a downhole motor for use in such a borehole electrical system. More specifically, the present invention relates to boosting the output of variable frequency drives employed to power electrical submersible pumps within wellbores.

BACKGROUND OF THE INVENTION

[0002] US 4 928 771 discloses a centrifugal pump which is lowered into a wellbore having a downhole three-phase electrical motor, wherein a single-phase AC power is supplied from the surface down a conductor, with the return being the casing. A phase converter converts the single-phase AC power to three-phase AC power downhole for driving the pump motor.

[0003] US 4 541 041 discloses a control for a voltage-fed series resonant inverter regulating the output voltage of the inverter from no-load to full-load and reducing circulating continuous current in the resonant elements which can result in excessive power dissipation during no-load and light-load operation.

[0004] Electrical power is frequently transmitted to subterranean locations within boreholes to power downhole equipment, such as electrical submersible pumps (ESPs). Normally three phase electrical power is transmitted from the surface over cables running between the well casing and the production tubing.

[0005] In some downhole applications, high voltage electrical power is required. For example, electrical motors for ESPs may require voltages of 1,000 to 5,000 volts at the surface. However, electrical drives capable of providing output voltages at the required level may not be available, or may not be economical even when available. When lower output voltage drives are employed in such situations, typically step-up transformers at the output of the drive are utilized to boost the voltage of power transmitted downhole. Step-up transformers add to the expense of the system, however, and add additional sources of failure or disturbance to the electrical system.

[0006] There is, therefore, a need in the art for a system allowing an electric drive having a maximum output voltage lower than required to be utilized to power downhole equipment while eliminating the need for step-up transformers. It would further be advantageous to smooth the output of a pulse width modulated variable frequency drive while boosting the output voltage.

SUMMARY OF THE INVENTION

[0007] To address the above-discussed deficiencies of the prior art, it is a primary object of the present invention to provide, for use in powering downhole equipment, a sine wave filter including an inductor for each phase (three inductors) and three delta- or Y-connected capacitors. The sine wave filter is coupled within a three phase power system at the surface, between the output of a variable frequency drive and a three phase power cable transmitting power to a borehole location to boost the output voltage of the drive. The sine wave filter is designed to have a resonant frequency higher than the maximum operational frequency of the drive, and a Q such that, at the maximum operational frequency of the drive, the filter provides a voltage gain equal to the ratio of the desired voltage to the drive's maximum output power at the maximum operational frequency. The sine wave filter also smooths the voltage waveform of a pulse width modulated variable frequency drive.

[0008] 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.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, wherein like numbers designate like objects, and in which:

FIGURE 1 depicts a three phase electrical power system employed to power downhole equipment according to one embodiment of the present invention;

FIGURES 2A-2B illustrate in greater detail circuit diagrams for sine wave filters employed within a three phase electrical power system for downhole equipment according to one embodiment of the present invention; and

FIGURE 3 depicts a plot of gain versus frequency for a sine wave filter employed within a three phase electrical power system according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0010] FIGURES 1 through 3, discussed below, and the various embodiment used to describe the principles of the present invention in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the invention. Those skilled in the art will understand that the principles of the present invention may be implemented in any suitably arranged device.

[0011] FIGURE 1 depicts a three phase electrical power system employed to power downhole equipment according to one embodiment of the present invention. The electrical power system 102 located at the surface of a borehole is coupled to a motor and pump 104 adapted for use within a borehole and disposed within the borehole by connection to tubing lowered within the well casing. Motor and pump assembly 104 includes an electrical submersible pump (ESP) in the exemplary embodiment, which may be of the type disclosed in U.S. Patent No. 5,845,709, coupled to an induction motor. The induction motor drives the ESP and is powered by three phase power transmitted over three phase transmission cable 106 electrically coupling motor and pump assembly 104 to a surface power system including generator 108 and drive 110.

[0012] Three phase transmission cable 106 include separate conductors for each electrical power phase and transmits power from the surface power system including generator 108, which produces three phase power, coupled to variable frequency drive (VFD) 110, designed to provide the appropriate voltage waveform at a selected frequency within a defined operating frequency range for powering motor and pump assembly 104. In the exemplary embodiment variable frequency drive 110 is a pulse width modulated (PWM) drive operationally regulated by a controller 112. Controller 112 for drive 110 changes the output frequency of drive 11o by altering the width of pulses forming the output voltage in accordance with the known art. Other suitable existing power electronics inverters may be employed for drive 110.

[0013] In the present invention, drive 110 may have a maximum output voltage (anywhere within the operating frequency range) which is lower than a voltage required for powering motor and pump assembly 104 disposed within the borehole. Drive 110 may be a low voltage drive having a maximum output voltage of only 480 volts (V), for example, while motor and pump assembly 104 may include a medium voltage motor requiring 1,000 V to 4,000 V at the surface. (Surface voltages are referenced since the cable 106, which may be thousands of feet long, will cause significant attenuation between the surface voltage and the voltage at the motor downhole.) Alternatively, drive 110 may have a maximum output voltage of 4,160 V, while a surface voltage of 5,000 V is requires to power motor and pump assembly 104. To boost the output voltage of drive 110, a sine wave filter 114 is coupled within the three phase power system 102 between the output of drive 110 and three phase cable 106 carrying power into the borehole.

[0014] While the sine wave filter 114 is preferably located at the surface, alternatively the sine wave filter may located downhole proximate to the motor, in which case the parameters of interest are the received input voltage at the input of the sine wave filter 114 received from the surface and the required motor voltage.

[0015] FIGURES 2A and 2B illustrate in greater detail circuit diagrams for sine wave filters employed within a three phase electrical power system for downhole equipment according to one embodiment of the present invention. Sine wave filter 114a depicted in FIGURE 2A includes three inductors L_A, L_B, and L_C each serially connected within a phase A, B and C, respectively, of the three phase power system between the output of the variable frequency drive and the three phase power cable 106 transmitting the power downhole. Sine wave filter 114a also includes three delta-connected capacitors C_{AB}, C_{BC}, and C_{AC} between phases A and B, between phases B and C, and between phases A and C, respectively, of the three phase power system.

[0016] Sine wave filter 114a depicted in FIGURE 2B also includes three inductors L_A, L_B, and L_C each serially connected within a phase A, B and C, respectively, of the three phase power system, but contains three Y-connected capacitors C_A, C_B, and C_C connected within phases A, B and C of the three phase power system, between the respectively phase and a common or neutral point.

[0017] In either implementation (114a in FIGURE 2A or 114b in FIGURE 2B), inductors L_A, L_B, and L_C each have the same inductance L, and either capacitors C_{AB}, C_{BC}, and C_{AC} or capacitors C_A, C_B, and C_C each have the same capacitance C (although the capacitance C of, for example, C_A is not necessarily the same as capacitance C of C_{AB}). The inductance L and capacitance C are selected to provide a filter voltage gain for three phase power at a maximum operational frequency of the variable frequency drive which is preferably equal to the ratio of the desired voltage for powering downhole equipment to the maximum output voltage of the drive.

[0018] FIGURE 3 depicts a plot of gain versus frequency for a sine wave filter employed within a three phase electrical power system according to one embodiment of the present invention. The sine wave filter 114a or 114b is tuned to have a resonant frequency f_0 which is offset from (higher than) the maximum operational frequency f_{max} of the variable frequency drive. The resonant frequency of the filter may be determined from:

$$f_0 = \frac{1}{2\pi\sqrt{3LC}} \,. \qquad (1)$$

The sine wave filter is also designed to have a quality factor Q, when excited by three phase power, which is greater than one. The quality factor Q may be determined from:

$$Q = \frac{3(2\pi) f_0 L}{R} \,, \qquad (2)$$

where R is the resistance of the sine wave filter components. The sine wave filter quality Q represents the gain of the filter at resonance, and thus the sine wave filter is capable of boosting the output voltage of the variable frequency drive by a factor equal to--or nearly equal to--the filter Q at the resonant frequency.

[0019] Because the drive frequency changes, however, it is not desirable to match the resonant frequency of the sine wave filter to the maximum operational frequency of the variable frequency drive. The high Q required to minimize filter losses under such circumstances would provide too much gain at the maximum operating frequency. Also, operating very close to the peak of the filter's resonance frequency would place operations on a very steep part of the filter's gain curve (gain plotted as a function of frequency, illustrated in FIGURE 3), making voltage regulation difficult.

[0020] Therefore, the sine wave filter is designed to have a resonant frequency offset from (and preferably higher than) maximum operating frequency of the variable frequency drive, on a portion of the frequency-dependent gain curve for the filter which is sufficiently gradual to permit voltage regulation (i.e., preferably within the range of voltage variances supported by the drive).

[0021] For example, if the maximum operational frequency of the variable frequency drive is 80 Hertz (Hz), the sine wave filter may be tuned to have a resonant frequency within the range of 90 Hz to 200 Hz, or more likely within the range of 90 Hz to 120 Hz. The filter is preferably always tuned for a resonant frequency higher than the drive's maximum operating frequency due to the need for a positive volts-per-Hertz ratio.

[0022] Since the gain G will vary with the frequency of the three phase power exciting the sine wave filter, the filter is preferably designed to provide a maximum gain G_{max} at the maximum operating frequency f_{max} of the drive. The maximum gain G_{max} is preferably equal to the ratio of the desired or required (surface) voltage to the maximum output voltage of the drive. In one of the examples described above, the sine wave filter would be designed to have a gain at the maximum operational frequency of the drive (e.g., 80 Hz) equal to 5,000/4,160, or about 1.2. In embodiments in which the filter resonant frequency is higher than the maximum operating frequency of the sine wave filter, the sine wave filter 114 will also have a minimum gain G_{min} at the minimum operational frequency f_{min} of the drive. It would be desirable, but is not necessary, for the minimum gain G_{min} to be greater than one.

[0023] The inductances and capacitances required to obtain a desired resonant frequency fo, and/or maximum gain G_{max} at the maximum operating frequency f_{max} of a particular generator/drive configuration, for the sine wave filter 114, may be determined utilizing existing electrical simulation programs.

[0024] Referring back to FIGURE 1, when excited by the output of drive 110 (utilizing power received from generator 108) filter 114 will (at least partially) resonate at the output frequency of drive 110, thus increasing the output voltage of filter 114 over the output voltage of drive 114 by a factor equal to the gain G of the filter 114 at the output frequency of drive 110. By tuning filter 114 to a resonant frequency above the maximum output frequency f_{max} of drive 110, the voltage boost provided by filter 114 will follow the output frequency of drive 110. In operation of electrical power system 102, the output voltage of filter 114 is connected by feedback loop 116 to controller 112. Controller 112 may thus monitor and regulate the output voltage of filter 114, altering the output voltage of filter 114 by controlling the output voltage and/or the output frequency of drive 110.

[0025] For a pulse width modulated variable frequency drive, sine wave filter 114 has the additional benefit of smoothing the voltage output of drive 110 into a very sinusoidal signal. For electrical submersible pumps, such smoothing of the power signal prevent problems from resonant frequencies and reflected waves, in addition to boosting the output voltage of the drive 110.

Claims

1. An electrical power system (102) for a motor within a wellbore, the system being **characterized by**:

a motor (104) being positioned in the wellbore;
a power electronics inverter (110) selectively producing an output voltage at an output, the output voltage being lower than a required voltage for powering the motor (104) positioned in the wellbore; and
a resonant circuit (114) connected to the output of the inverter (110), the resonant circuit (114) boosting the output voltage of the inverter (114) to the required voltage for powering the motor (104) positioned in the wellbore.

2. The electrical power system (102) as set forth in Claim 1 further comprising:

a pump within the wellbore, the motor (104) selectively driving the pump; and
a generator (108) located at a surface region proximate the wellbore, the generator (108) and the inverter (110) selectively producing an output voltage at an output, the output voltage lower than a required voltage for powering the motor (104).

3. The electrical power system (102) as set forth in Claim 1 or 2 wherein the resonant circuit (114) boosts the output voltage to the required voltage.

4. The electrical power system (102) as set forth in Claim 3 wherein the resonant circuit (114) further comprises:

an inductive-capacitive filter having a resonant frequency offset from a maximum operating frequency of the inverter (110), the filter having a gain at the maximum operating frequency of the inverter (110) approximately equal to the required voltage divided by the output voltage.

5. The electrical power system (102) as set forth in Claim 4 wherein the filter further comprises:

an inductance (L_A, L_B, L_C) serially connected in each phase of a three phase power transmission system coupled to the inverter (110); and
capacitances (C_A, C_B, C_C, C_{AB}, C_{BC}, C_{AC}) connected between phases of the three phase power transmission system.

6. The electrical power system (102) as set forth in Claim 1 or 2 further comprising:

a feedback connection from an output of the resonant circuit (114) to the inverter (110), the feedback connection allowing the inverter (110) to regulate an output voltage of the resonant circuit (114).

7. The electrical power system (102) as set forth in Claim 1 or 2 wherein a frequency dependent gain curve of the resonant circuit (114) is sufficiently gradual across an operating frequency range of the inverter (110) to permit voltage regulation over the operating frequency range.

8. The electrical power system (102) as set forth in Claim 1 or 2 wherein a frequency dependent gain curve of the resonant circuit (114) exhibits a maximum gain at a maximum operating frequency of the inverter (110) and a minimum gain at a minimum operating frequency of the inverter (110).

9. A method of powering a downhole motor (104) for use in a borehole electrical system (104) comprising:

producing an output voltage at an output of a power electronics inverter (110) which is lower than a required voltage for powering the motor (104) positioned in the borehole; and
boosting the output voltage of the power electronics inverter (110) to the required voltage for powering the motor (104) positioned in the borehole utilizing a resonant circuit (114) connected to the output of the inverter (110).

10. The method as set forth in Claim 9 wherein the step of boosting the output voltage towards the required voltage utilizing a resonant circuit (114) connected to the output of the inverter (110) further comprises:

boosting the output voltage to the required voltage.

11. The method as set forth in Claim 10 wherein the step of boosting the output voltage towards the required voltage utilizing a resonant circuit (114) connected to the output of the inverter (110) further comprises:

connecting an inductive-capacitive filter having a resonant frequency offset from a maximum operating frequency of the inverter (110) to the output of the inverter (110), the filter having a gain at the maximum operating frequency of the inverter (110) approximately equal to the required voltage divided by the output voltage.

12. The method as set forth in Claim 11 wherein the step of connecting a filter having a resonant frequency offset from a maximum operating frequency of the inverter (110) to the output of the inverter (110) further comprises:

serially connecting an inductance (L_A, L_B, L_C) in each phase of a three phase power transmission system coupled to the inverter (110); and
connecting capacitances (C_A, C_B, C_C, C_{AB}, C_{BC}, C_{AC}) between phases of the three phase power transmission system.

13. The method as set forth in Claim 9 further comprising:

providing a feedback connection from an output of the resonant circuit (114) to the inverter (110), the feedback connection allowing the inverter (110) to regulate an output voltage of the resonant circuit (114).

14. The method as set forth in Claim 9 wherein the step of boosting the output voltage towards the required voltage utilizing a resonant circuit (114) connected to the output of the inverter (110) further comprises:

boosting the output voltage utilizing a resonant circuit (114) having a frequency dependent gain curve which is sufficiently gradual across an operating frequency range of the inverter (110) to permit voltage regulation over the operating frequency range.

Patentansprüche

1. Elektrisches Leistungssystem (102) für einen Motor innerhalb eines Bohrlochs, wobei das System **dadurch gekennzeichnet ist, dass**:

- ein Motor (104) in dem Bohrloch positioniert ist;
- ein Leistungselektronikwechselrichter (110) selektiv eine Ausgangsspannung an einem Ausgang erzeugt, wobei die Ausgangsspannung niedriger als eine zum Antreiben des in dem Bohrloch positionierten Motors (104) erforderliche Spannung ist; und
- ein Resonanzkreis (114) mit dem Ausgang des Wechselrichters (110) verbunden ist, wobei der Resonanzkreis (114) die Ausgangsspannung des Wechselrichters (114) auf die zum Antreiben des in dem Bohrloch positionierten Motors (104) erforderliche Spannung erhöht.

2. Elektrisches Leistungssystem (102) nach Anspruch 1, weiterhin umfassend:

- eine Pumpe innerhalb des Bohrlochs, wobei der Motor (104) die Pumpe selektiv antreibt; und
- einen Generator (108), der in einem nahe an dem Bohrloch gelegenen Oberflächenbereich angeordnet ist, wobei der Generator (108) und der Wechselrichter (110) selektiv eine Ausgangsspannung an einem Ausgang erzeugen, wobei die Ausgangsspannung niedriger als eine zum Antreiben des Motors (104) erforderliche Spannung ist.

3. Elektrisches Leistungssystem (102) nach Anspruch 1 oder 2, wobei der Resonanzkreis (114) die Ausgangsspannung auf die erforderliche Spannung erhöht.

4. Elektrisches Leistungssystem (102) nach Anspruch 3, wobei der Resonanzkreis (114) weiterhin umfasst:

- ein induktiv-kapazitives Filter mit einer von einer maximalen Betriebsfrequenz des Wechselrichters (110) versetzten Resonanzfrequenz, wobei das Filter bei der maximalen Betriebsfrequenz des Wechselrichters (110) eine Verstärkung aufweist, die ungefähr gleich der erforderlichen Spannung geteilt durch die Ausgangsspannung ist.

5. Elektrisches Leistungssystem (102) nach Anspruch 4, wobei das Filter weiterhin umfasst:

- eine Induktivität (L_A, L_B, L_C), die in jeder Phase eines an den Wechselrichter (110) gekoppelten dreiphasigen

Leistungsübertragungssystems seriell verbunden ist; und
- Kapazitäten (C_A, C_B, C_C, C_{AB}, C_{BC}, C_{AC}), die zwischen Phasen des dreiphasigen Leistungsübertragungssystems verbunden sind.

6. Elektrisches Leistungssystem (102) nach Anspruch 1 oder 2, weiterhin umfassend:

- eine Rückkopplungsverbindung von einem Ausgang des Resonanzkreises (114) zu dem Wechselrichter (110), wobei die Rückkopplungsverbindung es dem Wechselrichter (110) erlaubt, eine Ausgangsspannung des Resonanzkreises (114) zu regulieren.

7. Elektrisches Leistungssystem (102) nach Anspruch 1 oder 2, wobei eine frequenzabhängige Verstärkungskurve des Resonanzkreises (114) über einem Betriebsfrequenzbereich des Wechselrichters (110) ausreichend graduell ist, um eine Spannungsregulierung über dem Betriebsfrequenzbereich zu erlauben.

8. Elektrisches Leistungssystem (102) nach Anspruch 1 oder 2, wobei eine frequenzabhängige Verstärkungskurve des Resonanzkreises (114) eine maximale Verstärkung bei einer maximalen Betriebsfrequenz des Wechselrichters (110) und eine minimale Verstärkung bei einer minimalen Betriebsfrequenz des Wechselrichters (110) aufweist.

9. Verfahren zum Antreiben eines Bohrlochmotors (104) zur Verwendung in einem elektrischen System (104) für ein Bohrloch, umfassend

- Erzeugung einer Ausgangsspannung an einem Ausgang eines Leistungselektronikwechselrichters (110), die niedriger als eine zum Antreibens des in dem Bohrloch positionierten Motors (104) erforderliche Spannung ist; und
- Erhöhen der Ausgangsspannung des Leistungselektronikwechselrichters (110) unter Verwendung eines mit dem Ausgang des Wechselrichters (110) verbundenen Resonanzkreises (114).

10. Verfahren nach Anspruch 9, wobei der Schritt des Erhöhens der Ausgangsspannung zu der erforderlichen Spannung hin unter Verwendung eines mit dem Ausgang des Wechselrichters (110) verbundenen Resonanzkreises (114) weiterhin umfasst:

- Erhöhung der Ausgangsspannung auf die erforderliche Spannung.

11. Verfahren nach Anspruch 10, wobei der Schritt des Erhöhens der Ausgangsspannung zu der erforderlichen Spannung hin unter Verwendung eines mit dem Ausgang des Wechselrichters (110) verbundenen Resonanzkreises (114) weiterhin umfasst:

- Verbinden eines induktiv-kapazitiven Filters, der eine von einer maximalen Betriebsfrequenz des Wechselrichters (110) versetzte Resonanzfrequenz aufweist, mit dem Ausgang des Wechselrichters (110), wobei das Filter bei der maximalen Betriebsfrequenz des Wechselrichters (110) eine Verstärkung aufweist, die ungefähr gleich der erforderlichen Spannung geteilt durch die Ausgangsspannung ist.

12. Verfahren nach Anspruch 11, wobei der Schritt des Verbindens eines Filters, der eine von einer maximalen Betriebsfrequenz des Wechselrichters (110) versetzte Resonanzfrequenz aufweist, mit dem Ausgang des Wechselrichters (110) weiterhin umfasst:

- serielles Verbinden einer Induktivität (L_A, L_B, L_C) in jeder Phase eines an den Wechselrichter (110) gekoppelten dreiphasigen Leistungsübertragungssystems; und
- Verbinden von Kapazitäten (C_A, C_B, C_C, C_{AB}, C_{BC}, C_{AC}) zwischen Phasen des dreiphasigen Leistungsübertragungssystems.

13. Verfahren nach Anspruch 9, weiterhin umfassend:

- Bereitstellung einer Rückkopplungsverbindung von einem Ausgang des Resonanzkreises (114) zu dem Wechselrichter (110), wobei die Rückkopplungsverbindung es dem Wechselrichter (110) erlaubt, eine Ausgangsspannung des Resonanzkreises (114) zu regulieren.

14. Verfahren nach Anspruch 9, wobei der Schritt des Erhöhens der Ausgangsspannung zu der erforderlichen Spannung hin unter Verwendung eines mit dem Ausgang des Wechselrichters (110) verbundenen Resonanzkreises (114) weiterhin umfasst:

- Erhöhen der Ausgangsspannung unter Verwendung eines Resonanzkreises (114) mit einer frequenzabhängigen Verstärkungskurve, die über einer Betriebsfrequenz des Wechselrichters (110) ausreichend graduell ist, um eine Spannungsregulierung über dem Betriebsfrequenzbereich zu erlauben.

Revendications

1. Système d'alimentation électrique (102) pour un moteur à l'intérieur d'un puits de forage, le système étant **caractérisé par** :

un moteur (104) étant positionné dans le puits de forage ;
un inverseur (110) d'électronique d'alimentation produisant sélectivement une tension de sortie à une sortie, la tension de sortie étant inférieure à une tension requise pour alimenter le moteur (104) positionné dans le puits de forage ; et
un circuit résonnant (114) connecté à la sortie de l'inverseur (110), le circuit résonnant (114) augmentant la tension de sortie de l'inverseur (114) jusqu'à la tension requise pour alimenter le moteur (104) positionné dans le puits de forage.

2. Système d'alimentation électrique (102) selon la revendication 1 comprenant en outre :

une pompe à l'intérieur du puits de forage, le moteur (104) entraînant sélectivement la pompe ; et
un générateur (108) situé au niveau d'une région de surface à proximité du puits de forage, le générateur (108) et l'inverseur (110) produisant sélectivement une tension de sortie à une sortie, la tension de sortie inférieure à une tension requise pour alimenter le moteur (104).

3. Système d'alimentation électrique (102) selon la revendication 1 ou 2 dans lequel le circuit résonnant (114) augmente la tension de sortie jusqu'à la tension requise.

4. Système d'alimentation électrique (102) selon la revendication 3 dans lequel le circuit résonnant (114) comprend en outre :

un filtre inductif-capacitif ayant une fréquence de résonance décalée par rapport à une fréquence opérationnelle maximum de l'inverseur (110), le filtre ayant un gain à la fréquence opérationnelle maximum de l'inverseur (110) approximativement égal à la tension requise divisée par la tension de sortie.

5. Système d'alimentation électrique (102) selon la revendication 4 dans lequel le filtre comprend en outre :

une inductance (L_A, L_B, L_C) connectée en série dans chaque phase d'un système de transmission d'alimentation triphasé couplé à l'inverseur (110) ; et
des capacitances (C_A, C_B, C_C, C_{AB}, C_{BC}, C_{AC}) connectées entre des phases du système de transmission d'alimentation triphasé.

6. Système d'alimentation électrique (102) selon la revendication 1 ou 2 comprenant en outre :

une connexion de retour d'une sortie du circuit résonnant (114) jusqu'à l'inverseur (110), la connexion de retour permettant que l'inverseur (110) régule une tension de sortie du circuit résonnant (114).

7. Système d'alimentation électrique (102) selon la revendication 1 ou 2 dans lequel une courbe de gain dépendant de la fréquence du circuit résonnant (114) est suffisamment graduelle sur une plage de fréquence opérationnelle de l'inverseur (110) pour permettre une régulation de tension sur la plage de fréquence opérationnelle.

8. Système d'alimentation électrique (102) selon la revendication 1 ou 2 dans lequel une courbe de gain dépendant de la fréquence du circuit résonnant (114) affiche un gain maximum à une fréquence opérationnelle maximum de l'inverseur (110) et un gain minimum à une fréquence opérationnelle minimum de l'inverseur (110).

9. Procédé d'alimentation d'un moteur (104) de fond de trou destiné à une utilisation dans un système électrique (102) de fond de trou comprenant :

la production d'une tension de sortie à une sortie d'un inverseur (110) d'électronique d'alimentation qui est inférieure à une tension requise pour alimenter le moteur (104) positionné dans le puits de forage ; et l'augmentation de la tension de sortie de l'inverseur (110) d'électronique d'alimentation jusqu'à la tension requise pour alimenter le moteur (104) positionné dans le puits de forage en utilisant un circuit résonant (114) connecté à la sortie de l'inverseur (110).

10. Procédé selon la revendication 9 dans lequel l'étape d'augmentation de la tension de sortie vers la tension requise en utilisant un circuit résonant (114) connecté à la sortie de l'inverseur (110) comprend en outre :

l'augmentation de la tension de sortie jusqu'à la tension requise.

11. Procédé selon la revendication 10 dans lequel l'étape d'augmentation de la tension de sortie vers la tension requise en utilisant un circuit résonant (114) connecté à la sortie de l'inverseur (110) comprend en outre :

la connexion d'un filtre inductif-capacitif ayant une fréquence de résonance décalée par rapport à une fréquence opérationnelle maximum de l'inverseur (110) à la sortie de l'inverseur (110), le filtre ayant un gain à la fréquence opérationnelle maximum de l'inverseur (110) approximativement égal à la tension requise divisée par la tension de sortie.

12. Procédé selon la revendication 11 dans lequel l'étape de connexion d'un filtre ayant une fréquence de résonance décalée par rapport à une fréquence opérationnelle maximum de l'inverseur (110) à la sortie de l'inverseur (110) comprend en outre :

la connexion en série d'une inductance (L_A, L_B, L_C) dans chaque phase d'un système de transmission d'alimentation triphasé couplé à l'inverseur (110) ; et
la connexion de capacitances (C_A, C_B, C_C, C_{AB}, C_{BC}, C_{AC}) entre des phases du système de transmission d'alimentation triphasé.

13. Procédé selon la revendication 9 comprenant en outre :

la prévision d'une connexion de retour d'une sortie du circuit résonnant (114) jusqu'à l'inverseur (110), la connexion de retour permettant que l'inverseur (110) régule une tension de sortie du circuit résonnant (114).

14. Procédé selon la revendication 9 dans lequel l'étape d'augmentation de la tension de sortie vers la tension requise en utilisant un circuit résonant (114) connecté à la sortie de l'inverseur (110) comprend en outre :

l'augmentation de la tension de sortie en utilisant un circuit résonant (114) ayant une courbe de gain dépendant de la fréquence qui est suffisamment graduelle sur une plage de fréquence opérationnelle de l'inverseur (110) pour permettre une régulation de tension sur la plage de fréquence opérationnelle.

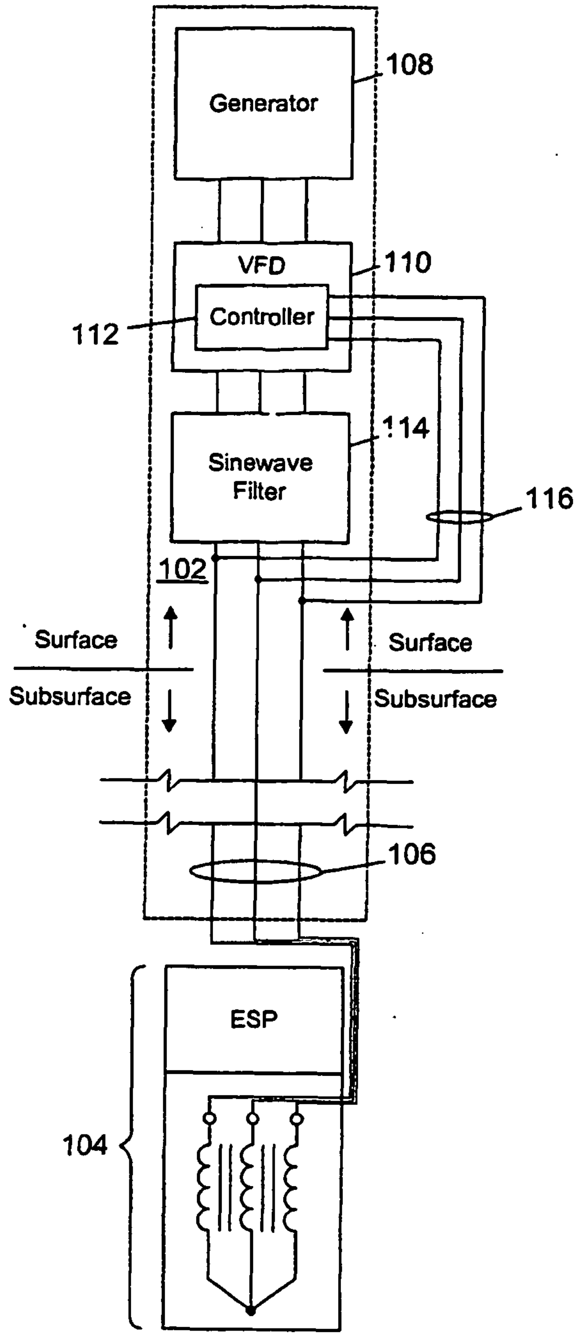

Figure 1

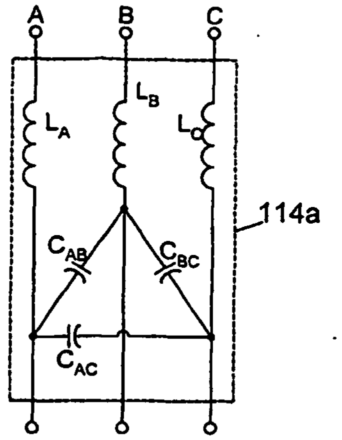

Figure 2A

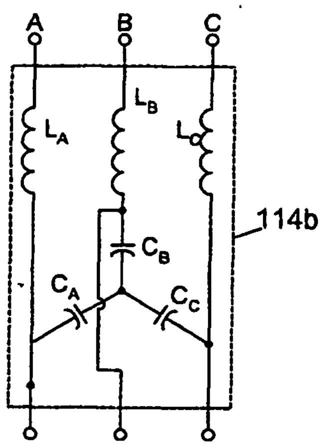

Figure 2B

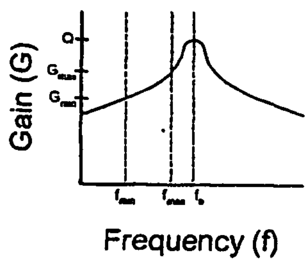

Figure 3

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 4928771 A **[0002]**
- US 4541041 A **[0003]**
- US 5845709 A **[0011]**