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(54) **METHOD FOR OPERATING A WELL USING A PUMP ASSEMBLY WITH A VARIABLE-FREQUENCY DRIVE**

VERFAHREN ZUM BETREIBEN EINES BOHRLOCHS MITHILFE EINER PUMPENANORDNUNG MIT EINEM ANTRIEB VON VARIABLER FREQUENZ

PROCÉDÉ D'EXPLOITATION D'UN Puits AU MOYEN D'UNE INSTALLATION DE POMPAGE MUNIE D'UN ENTRAINEMENT RÉGLABLE EN FRÉQUENCE

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(56) References cited:  
**WO-A1-94/14233 RU-A- 2010 146 609**  
**RU-C1- 2 119 578 RU-C1- 2 322 571**  
**RU-C2- 2 181 829 US-A- 5 844 397**  
**US-A- 6 043 995 US-A1- 2008 247 880**  
**US-B1- 6 481 973**

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**EP 2 990 594 B1**

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**Description****FIELD OF THE INVENTION**

5 [0001] The invention pertains to the oil production and can be used in wells equipped with electric pumps namely electric submersible pumps.

**BACKGROUND OF THE INVENTION**

10 [0002] Electric submersible pumps provided with variable frequency drives are well known on the field of oil production. US2008247880 discloses a downhole pump provided with a controller configured to reduce the output voltage of the variable speed drive and sweep through a range of output frequencies. There is a known method of exploitation of wells by electric pump with variable-frequency drive (patent RF 2426867) based on the continuous operation of the pump and including startup of pump with defined process rate of change of frequency of supply voltage when the pump reaches defined frequency of the stationary mode with acceleration in case of pump-off and supply of liquid by pump in the stationary mode at defined frequency, for compensation of the unstable feed and to maintain stable balance between liquid takeoff from the well and inflow of fluid from formation they periodically perform cycles consisting of alternation of pumping of pumping off of fluid and accumulation of fluid in the well, the pumping off is performed through modulation of frequency in the range of values corresponding to parameters of maintaining of pump delivery rate with subsequent maintenance of maximum frequency at which pump does not resume delivery and in the phase of inflow of fluid into well in the current cycle they perform modulation of the frequency of supply voltage of the electric pump in the frequency range corresponding to the changing during fluid inflow parameters of pump in when delivery is stopped and resumed, and when during the inflow of fluid the intake pressure of the pump reaches defined value they resume delivery of fluid by pump after that the cycle is repeated and when in the current cycle the frequency of resuming the delivery does not exceed the defined frequency the pump is switched into stationary mode which differing by the fact that in case of pump starvation when it is brought to the defined frequency of the stationary mode during defined time in the interval of values of resuming and stopping of pump delivery the additional modulation of frequency of resuming fluid delivery is performed. Additional modulation is performed before the pumping is resumed which is performed at the frequency with defined deviation from the frequency achieved before additional modulation of pump starvation frequency after that it is necessary to continue to bring the pump to defined frequency of stationary mode with defined process rate of stabilization of well.

25 [0003] In this method modulation of frequency is performed for bringing the pump to defined frequency of stationary mode.

30 [0004] There is a known method of exploitation of well equipped with electric submersible pump with variable frequency drive (patent RF 2421605), which is used for stabilization of wells equipped with electric submersible pump (ESP) after workover which implies change of the frequency of supply voltage of electric motor depending on the watercut of produced well fluid.

35 [0005] However in this method the frequency of supply voltage is changed only when the well is brought to pumpdown mode.

40 [0006] There is a known method of exploitation of low-flow rate wells by electric pump with variable frequency drive and device (Patent RU 2119578), based on periodic repetition of cycles including startup of the pump with increasing frequency of supply voltage and supply fluid by pump at defined frequency and after reaching defined pressure in the tubing string in the current cycle the frequency of supply voltage is reduced until pump stops delivery subsequently maximum frequency is maintained to ensure inflow of fluid from formation and pump does not resume delivery, after reaching defined pressure at the pump intake during inflow the cycle is repeated and pump delivery is resumed by increasing its frequency. This invention is treated by its authors as prototype.

45 [0007] The prototype includes the following disadvantages:

[0008] Sophisticated structure for implementation of the method and device, namely, usage of additional downhole equipment - thermal and pressure measurement system installed under downhole motor which increases the cost of the method of exploitation of the well and prevents from application of this method with high temperature of formation fluid (above 90° C), due to failures of downhole electronics.

50 [0009] The method is suitable only for low production wells.

[0010] The time when delivery is stopped is determined based on the power and bench test characteristics of the pump which causes significant error because testing is performed on fluid characteristics of which do not match real fluid characteristics in each specific well.

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**SUMMARY OF THE INVENTION**

[0011] The task of the declared method and device is assurance of the ability to operate both in low production wells

and in wells with high inflow, i.e. in high production wells. Simplification of the device due to absence of submersible sensors. Increased lifespan of the pumping unit because it can run with higher capacity equipment as the declared method of work supports modes significantly exceeding limit parameters.

[0012] The said tasks is addressed by the fact that the method of exploitation of wells by pumping unit with variable frequency drive comprises periodic repetition of the cycles including pumpdown, search of frequency when delivery stops and accumulation and to ensure pumpdown of such amount of fluid from the well which is equal to its inflow it is necessary to choose pumping unit with high capacity in comparison with inflow of fluid from formation into well and during performance of cycles it is necessary to correct the ratio of pumdown-accumulation time depending on the results of the work in the previous cycles until the ratio pumpdown-accumulation time stops to change and the time when delivery stops is determined based on the equation of the values of the current torque on the shaft of downhole motor and check torque on the which is pre-calculated based stepwise drop of torque on the shaft of the engine in the point when the delivery stops during decrease of the frequency of supply voltage.

[0013] The device for implementation of the method contains pumping unit consisting of placed in the tubing string electric submersible pump and downhole motor suspended on the tubing string, the downhole motor by conductive cable is linked with frequency converter on the surface and control device. The device also contains matching transformer, frequency, current, torque, power measurement unit, communication unit, indication and control unit. The conductive cable is linked with the first input-output of matching transformer, the second input-output of matching transformer is linked with input-output of frequency converter, the second input-output of frequency converter is linked with power supply, the third input-output of the frequency converter is linked with the first input-output of the frequency, current, torque, power measurement unit, the second input-output of this unit is linked with the first input-output of communication unit, the third input-output of the frequency, current, torque, power measurement unit is linked with the first input-output of controller, the second input-output of the controller is linked with indication and control unit. All signals received by units located on the surface are transmitted via conductive cable directly from the shaft of the downhole motor.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The invention is explained by drawing where

Fig. 1 is a schematic illustration of pumping unit with variable frequency drive which is used for exploitation of a well.

Fig. 2 is a diagram of the operating algorithm of the unit.

Fig. 3 is an operation chart in cycles pumpdown-accumulation of stabilized cyclic mode,

wherein A - is start of transition to pumpdown mode; B - is start of searching of delivery stopping frequency; C - is start of accumulation; D - is pumpdown time; E - is accumulation time; F - is search of frequency when delivery stops; a - is frequency; b - is current; c - is torque; d - is MK 2; e - is MK 1.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] The device contains pumping unit 2 placed in the production casing string 1 consisting of electric submersible pump 3 and downhole motor 4 suspended on the dowhole pipe string 5 and the downhole motor 4 by conducting cable 6 is linked to devices located on surface namely its first input-output is linked with the input-output of matching transformer 7. The second input-output of matching transformer is linked with input-output of frequency converter 8. The second input-output of the frequency converter 8 is linked with power supply 9, the third input-output is linked with the first input-output of the frequency, current, torque, power measurement unit 10. The second input-output of the current, torque, power measurement unit is linked with the communication unit 11, the second input-output of communication unit is linked with the fourth input-output of the frequency converter 8, the third input-output of communication unit is linked with the first input-output of controller 12, the second input-output of controller with indication and control unit 13. Characteristics used for implementation of the methods are frequency on shaft of downhole motor 4, current, torque, setpoints MK1 and MK2.

[0016] MK1 -s torque generated by downhole motor in the point where fluid delivery stops.

[0017] MK2 is a torque exceeding MK1 by 3-10%.

## IMPLEMENTATION OF THE METHOD AND DEVICE

[0018] The device operates as follows.

[0019] Pumping unit 2 using conductive cable 6 via matching transformer 7 is connected with frequency converter 8

to which power is supplied from power unit 9. Frequency converter 8 converts commercial frequency voltage 50 Hz into the downhole motor voltage with variable frequency in the range from 0 to 300 Hz. The frequency range of pumping unit 2 with electric submersible motor 4 and electric submersible pump 3 practically ranges from 30 to 70 Hz.

**[0020]** Converter frequency 8 is provided with frequency, current, torque, power measurement unit 10 and measures output frequency of drive, current of downhole motor 4, torque, power supplied to downhole motor 4. All parameters are computed in real time with period of around 200 millisecond and are stored in digital format in the memory with frequency, torque measurement unit 10. Frequency converter 8 is provided with communication unit 11 which provides access for all devices to all parameters of frequency converter 8 and via which control commands are supplied by frequency converter 8.

**[0021]** Controller 12 provided with indication and control unit 13 continuously reads required parameters (frequency, current, voltage, power, torque, etc.) and transmit commands in accordance with control algorithm.

**[0022]** When exploitation of the well starts to measure the torque at which the delivery stops the pump unit is accelerated to the frequency at which the fluid delivery resumes. Then frequency is gradually reduced and the engine torque is continuously controlled. Usually, in case of gradual reduction of the frequency the torque on the engine shaft is gradually reduced. When the point when delivery stops is reached (idle run) the torque drops stepwise which is clear on the graphic screen of the controller (See Fig.3). This torque value (in percent) is chosen as MK1 setpoint. The second setpoint MK2 is set 3-10% above the first one.

**[0023]** The method of exploitation of well by pumping unit with variable-frequency drive comprises periodic repetition of cycles including pumpdown, search of frequency for stopping delivery and accumulation to ensure the extraction of such amount of fluid from well which is equal to its inflow it is necessary to choose pumping unit with higher capacity in comparison with the well inflow from formation and during performance of cycles the pumpdown-accumulation ratio is corrected depending on the results of the previous cycle until the pumpdown-accumulation cycle stops changing and the moment when delivery stops is determined based on the equation of the values of current torque on the shaft of the downhole motor 4 and test torque which is preliminarily determined based on steplike drop of torque on the shaft of downhole motor 4 in the point when delivery stops when frequency of supply voltage decreases.

**[0024]** The operation of the device and implementation of the method is in accordance with flow-chart provided on Fig.2.

**[0025]** After startup of the unit (start) it is operated at the frequency of delivery (delivery means delivery of fluid). When delivery starts the controller 12 receives signal from electric motor 4 frequency, current, torque, power measurement unit 10 and torque on the shaft of downhole motor 4 when delivery stops is measured. This value is also displayed on the indication and control unit 13. The delivery is stopped by gradual reduction of the frequency of supply voltage, the signal from controller 12 is transmitted via communication unit 11, frequency converter 8 to downhole motor 4. The rate of change of frequency is continuously compared with the rate of change of torque on the shaft of downhole motor 4. When fluid is delivered the rate of change of frequency and torque are proportional while when the point is achieved at which delivery stops the value of torque on the shaft of downhole motor 4 drops in stepwise manner because no energy is spent to lift the fluid (See Fig. 3 that provides charts of stabilized cyclic mode). Motor shaft torque (in %) is assumed as setpoint (MK1).

**[0026]** Depending on the performance of the unit and expected inflow the pumpdown and accumulation time is defined using the following ratio:

$$\frac{\text{Expected inflow}}{\text{Performance of unit}} = \frac{\text{Pumpdown time}}{\text{Pumpdown time} + \text{accumulation time}}$$

**[0027]** The unit is run in pumpdown mode for defined time and then it is switched to the mode of searching for frequency at which delivery stops. The frequency is determined when the current shaft torque of the downhole motor 4 is equal to check torque MK1. If frequency is not determined the pumdown time is increased and cycle is repeated. If frequency is determined the unit is switched to accumulation mode at this frequency and is run for defined time. In each cycle it is necessary to check whether the pumpdown time and accumulation time ratio changes. If this ratio does not change it means that well runs in the stabilized cycling mode when inflow of fluid into well is equal to its extraction (the pumpdown-accumulation time ratio with constant pumpdown and accumulation time changes in the mode of searching for delivery stopping frequency because depending on the inflow the delivery stops at different frequencies, i.e. at different time).

**[0028]** If pumdown-accumulation time ratio changes it is corrected. It is an automatic process using controller 12 that receives information from unit of measurement of frequency, current, torque, power 10 of the downhole motor 4. Controller 12 transmits control signals via communication unit 11 to frequency converter 8 which via matching transformer 7 transmits signals to conducting cable 6 to equalize the inflow of fluid from formation and its extraction. If the pumpdown-accumulation ratio exceeds the set limits, i.e. it cannot be adjusted do to various reasons the well is shut and then re-started.

[0029] The invention allows for optimization of production of oil by pumpdowns of such amount of fluid which is equal to its inflow in the well. The method proposes to use pumping unit with higher capacity in comparison with well fluid inflow. The method is based on adjustment of the amount of pumped down fluid from well by periodic repletion of cycles and each of such cycles includes three modes:

5 [0030] The first modes is an operation at the frequency at which fluid is pumped down;

[0031] The second mode is the mode of searching for frequency for stopping the delivery;

[0032] The third mode is operation at the frequency at which delivery is stopped.

[0033] The modes are illustrated on Fig.3.

[0034] The method is implemented as follows:

10 [0035] After the first startup wait for the delivery and measure check shaft torque of downhole motor at which the delivery stops when motor speed drops. The check torque is assumed as a setpoint for switching the modes. Depending on the inflow based on the results of the previous cycles the pumpdown and accumulation time ratio is corrected until this ratio stops changing i.e. until the well is stabilized in the cyclic mode when inflow from formation is equal to the amount of extracted fluid.

15 **COMMERCIAL APPLICABILITY**

[0036] The device is designed using available and commercially produced accessories.

20 [0037] The main difference from the prototype in terms of the method is the fact that in the proposed method the cyclic mode is main mode both during well stabilization and during current exploitation.

[0038] The method and device are designed for all wells including low production wells. In high production wells the method allows for application of submersible pumps with knowingly higher capacity in comparison with well productivity which helps to extend the lifespan of the unit because the it is run with loads which are significantly lower than limit loads.

25 [0039] The device does not require any downhole sensors which simplifies this device. In the proposed device all signals are transmitted to units located on the surface via conductive cable directly from downhole motor shaft.

[0040] The torque at which delivery stops is determined based on the actual fluid properties and actual specifications of the pumping unit by measurement of the rate of change of the rotating torque of downhole motor shaft. It is known that when frequency drops when delivery stops, i.e when engine runs in idle mode the rotating torque of the shaft drops stepwise which allows for determination of the torque when delivery stops taking into account all actual conditions, i.e. the properties of fluid and specifications of the unit.

30 [0041] This method of well exploitation using the proposed device allows for usage of pumping unit with higher capacity in comparison with well inflow for delivery of the best results of in increasing the production of oil This simplifies sizing of the pumping unit and extends time between overhauls during operation because the unit in this case runs in derated operating modes which ensures.

35 [0042] Thus the above demonstrates delivery of technical result

PARTS LIST

40 [0043]

Production casing string 1

Pumping unit 2

Electrical submersible pump 3

Downhole motor 4

45 Downhole pipe string 5

Conductive cable 6

Matching transformer 7

frequency converter 8

Power supply 9

50 Frequency, current, torque, power measurement unit 10

Communication unit 11

Controller 12

Indication and control unit 13

55 **Claims**

1. A method of exploitation of a well using a pumping unit (2) with a variable-frequency drive, comprising periodically

repeating pumpdown, search of stopping delivery frequency, and accumulation cycles, the method **characterized by**:

selecting a pumping unit (2) with higher production capacity in comparison with inflow of fluid from formation into the well for ensuring extracting an amount of the fluid equal to the inflow;  
 5 during the cycles correcting the pumpdown-accumulation ratio depending on the results of previous cycles until the pumpdown-accumulation time ratio stops changing; and  
 determining when the delivery stops based on a current torque on a shaft of a downhole motor (4) being equal to a check torque, wherein the check torque is predetermined based on a stepwise drop of a torque on the shaft of the downhole motor at a point when the delivery stops at a decrease of a supply voltage.  
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2. A device for exploitation of a well using a pumping unit (2) with a variable-frequency drive and periodically repeating pumpdown, search of stopping delivery frequency, and accumulation cycles, the device **characterized by**:

a pumping unit (2) disposed in a production casing string (1), the pumping unit (2) comprising an electrical submersible pump (3) and a downhole motor (4) suspended on a downhole pipe string (5);  
 15 the downhole motor (4) connected by a conductive cable (6) to a frequency converter (8) and to a controlling device, the frequency converter (8) and the controlling device being disposed on a surface;  
 a matching transformer (7), a frequency, current, torque, and power measurement unit (10), a communication unit (11), an indication and control unit (13), wherein the conductive cable (6) is coupled with a first input-output of the matching transformer (7), a second input-output of the matching transformer (7) is coupled with an input-output of the frequency converter (8), a second input-output of the frequency converter (8) is connected with a power supply unit (9), a third input-output of the frequency converter (8) is coupled with the first input-output of the frequency, current, torque, and power measurement unit (10), a second input-output of the measurement unit is coupled with a first input-output of the communication unit (11), a second input-output of communication unit (11) is coupled with a fourth input-output of the frequency converter (8), a third input-output of the communication unit (11) is coupled with a first input-output of controller (12), a second input-output of the controller (12) is coupled with an indication and control unit (13) and wherein all signals are transmitted to units disposed on the surface via the conductive cable (6) directly from the shaft of the downhole motor (4).  
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## Patentansprüche

1. Verfahren zur Ausbeutung eines Bohrlochs unter Verwendung einer Pumpeinheit (2) mit einem Antrieb mit variabler Frequenz, umfassend sich periodisch wiederholende Zyklen aus Abpumpen, Suche nach der Förderstopp-Frequenz und Akkumulation, wobei das Verfahren durch Folgendes **gekennzeichnet** ist:  
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Auswählen einer Pumpeinheit (2) mit einer höheren Förderkapazität als der Einstrom von Fluid aus der Formation in das Bohrloch, um zu gewährleisten, dass eine Fluidmenge extrahiert wird, die dem Einstrom entspricht;  
 während der Zyklen Korrigieren des Verhältnisses von Abpumpen zu Akkumulation in Abhängigkeit von den Ergebnissen vorhergehender Zyklen, bis sich das Verhältnis von Abpump- zu Akkumulationszeit nicht mehr verändert; und  
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Bestimmen, wann die Förderung stoppt, auf der Grundlage, dass ein aktuelles Drehmoment an einer Welle eines Bohrlochsohlenmotors (4) gleich einem Kontrolldrehmoment ist, wobei das Kontrolldrehmoment vorab festgelegt wird auf Grundlage eines schrittweisen Abfalls eines Drehmoments an der Welle der Bohrlochsohlenmotor zu einem Zeitpunkt, an dem die Förderung bei einer Verringerung einer Versorgungsspannung stoppt.  
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2. Vorrichtung zur Ausbeutung eines Bohrlochs unter Verwendung einer Pumpeinheit (2) mit einem Antrieb mit variabler Frequenz und sich periodisch wiederholender Zyklen aus Abpumpen, Suche nach der Förderstopp-Frequenz und Akkumulation, wobei die Vorrichtung durch Folgendes **gekennzeichnet** ist:  
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eine Pumpeinheit (2), die in einem Produktionsrohrstrang (1) angeordnet ist, wobei die Pumpeinheit (2) eine elektrische Tauchpumpe (3) und einen Bohrlochsohlenmotor (4) umfasst, der an einem Bohrlochrohrstrang (5) abgehängt ist;

wobei der Bohrlochsohlenmotor (4) durch ein leitfähiges Kabel (6) mit einem Frequenzumrichter (8) und mit einer Steuervorrichtung verbunden ist, wobei der Frequenzumrichter (8) und die Steuervorrichtung an einer Oberfläche angeordnet sind;

einen Anpassungstransformator (7), eine Frequenz-, Strom-, Drehmoment- und Leistungsmesseinheit (10), eine Kommunikationseinheit (11), eine Anzeige- und Steuereinheit (13), wobei das leitfähige Kabel (6) mit einem  
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ersten Eingang-Ausgang des Anpassungstransformators (7) verbunden ist, ein zweiter Eingang-Ausgang des Anpassungstransformators (7) mit einem Eingang-Ausgang des Frequenzumrichters (8) verbunden ist, ein zweiter Eingang-Ausgang des Frequenzumrichters (8) mit einer Stromversorgungseinheit (9) verbunden ist, ein dritter Eingang-Ausgang des Frequenzumrichters (8) mit dem ersten Eingang-Ausgang der Frequenz-, Strom-, Drehmoment- und Leistungsmesseinheit (10) verbunden ist, ein zweiter Eingang-Ausgang der Messeinheit mit einem ersten Eingang-Ausgang der Kommunikationseinheit (11) verbunden ist, ein zweiter Eingang-Ausgang der Kommunikationseinheit (11) mit einem vierten Eingang-Ausgang des Frequenzumrichters (8) verbunden ist, ein dritter Eingang-Ausgang der Kommunikationseinheit (11) mit einem ersten Eingang-Ausgang der Steuerung (12) verbunden ist, ein zweiter Eingang-Ausgang der Steuerung (12) mit einer Anzeige- und Steuereinheit (13) verbunden ist und wobei alle Signale über das leitfähige Kabel (6) direkt von der Welle des Bohrlochsohlenmotors (4) an Einheiten übertragen werden, die an der Oberfläche angeordnet sind.

## Revendications

1. Procédé d'exploitation d'un puits à l'aide d'une unité de pompage (2) avec un entraînement à fréquence variable, comprenant une répétition périodique de cycles de pompage, recherche de la fréquence d'arrêt du refoulement et accumulation, **caractérisé en ce qu'il** comprend :

la sélection d'une unité de pompage (2) d'une capacité de production supérieure à l'afflux de liquide provenant de la formation dans le puits afin d'assurer l'extraction d'une quantité de liquide égale à l'afflux ;  
la correction, au cours des cycles, du rapport entre le pompage et l'accumulation en fonction des résultats de cycles antérieurs jusqu'à ce que le rapport entre les temps de pompage et d'accumulation cesse de varier ; et  
la détermination du moment où le refoulement s'arrête quand un couple instantané sur un arbre d'un moteur en fond de trou (4) est égal à un couple d'arrêt, le couple d'arrêt étant prédéterminé sur la base d'une baisse graduelle d'un couple sur l'arbre du moteur en fond de trou jusqu'à un point où le refoulement s'arrête avec une baisse de la tension d'alimentation.

2. Dispositif d'exploitation d'un puits à l'aide d'une unité de pompage (2) avec un entraînement à fréquence variable et une répétition périodique de cycles de pompage, recherche de la fréquence d'arrêt du refoulement et accumulation, **caractérisé en ce qu'il** comprend :

une unité de pompage (2) disposée dans une colonne de tubage de production (1), l'unité de pompage (2) comprenant une pompe submersible électrique (3) et un moteur en fond de trou (4) suspendu à un train de tiges en fond de trou (5) ;  
le moteur en fond de trou (4) connecté par un câble conducteur (6) à un convertisseur de fréquence (8) et à un dispositif de commande, le convertisseur de fréquence (8) et le dispositif de commande étant disposés sur une surface ;  
un transformateur d'adaptation (7), une unité de mesure de la fréquence, du courant, du couple et de la puissance (10), une unité de communication (11), une unité d'indication et de commande (13), le câble conducteur (6) étant couplé à une première entrée-sortie du transformateur d'adaptation (7), une deuxième entrée-sortie du transformateur d'adaptation (7) étant couplée à une entrée-sortie du convertisseur de fréquence (8), une deuxième entrée-sortie du convertisseur de fréquence (8) étant connectée à une unité d'alimentation en énergie (9), une troisième entrée-sortie du convertisseur de fréquence (8) étant couplée à la première entrée-sortie de l'unité de mesure de la fréquence, du courant, du couple et de la puissance (10), une deuxième entrée-sortie de l'unité de mesure étant couplée à une première entrée-sortie de l'unité de communication (11), une deuxième entrée-sortie de l'unité de communication (11) étant couplée à une quatrième entrée-sortie du convertisseur de fréquence (8), une troisième entrée-sortie de l'unité de communication (11) étant couplée à une première entrée-sortie du contrôleur (12), une deuxième entrée-sortie du contrôleur (12) étant couplée à une unité d'indication et de commande (13) et tous les signaux étant transmis aux unités disposées sur la surface via le câble conducteur (6) directement à partir de l'arbre du moteur en fond de trou (4).

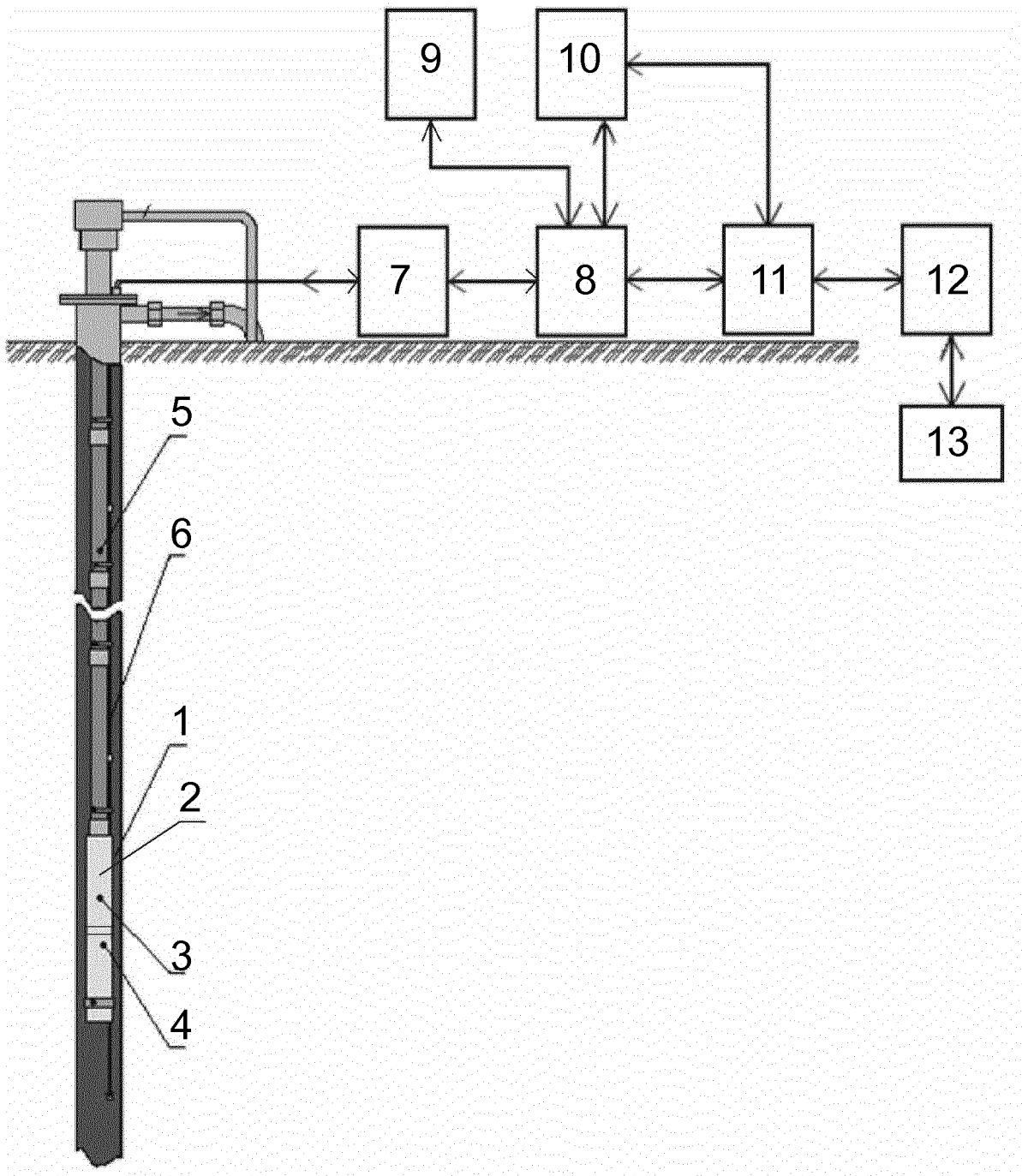


Fig. 1



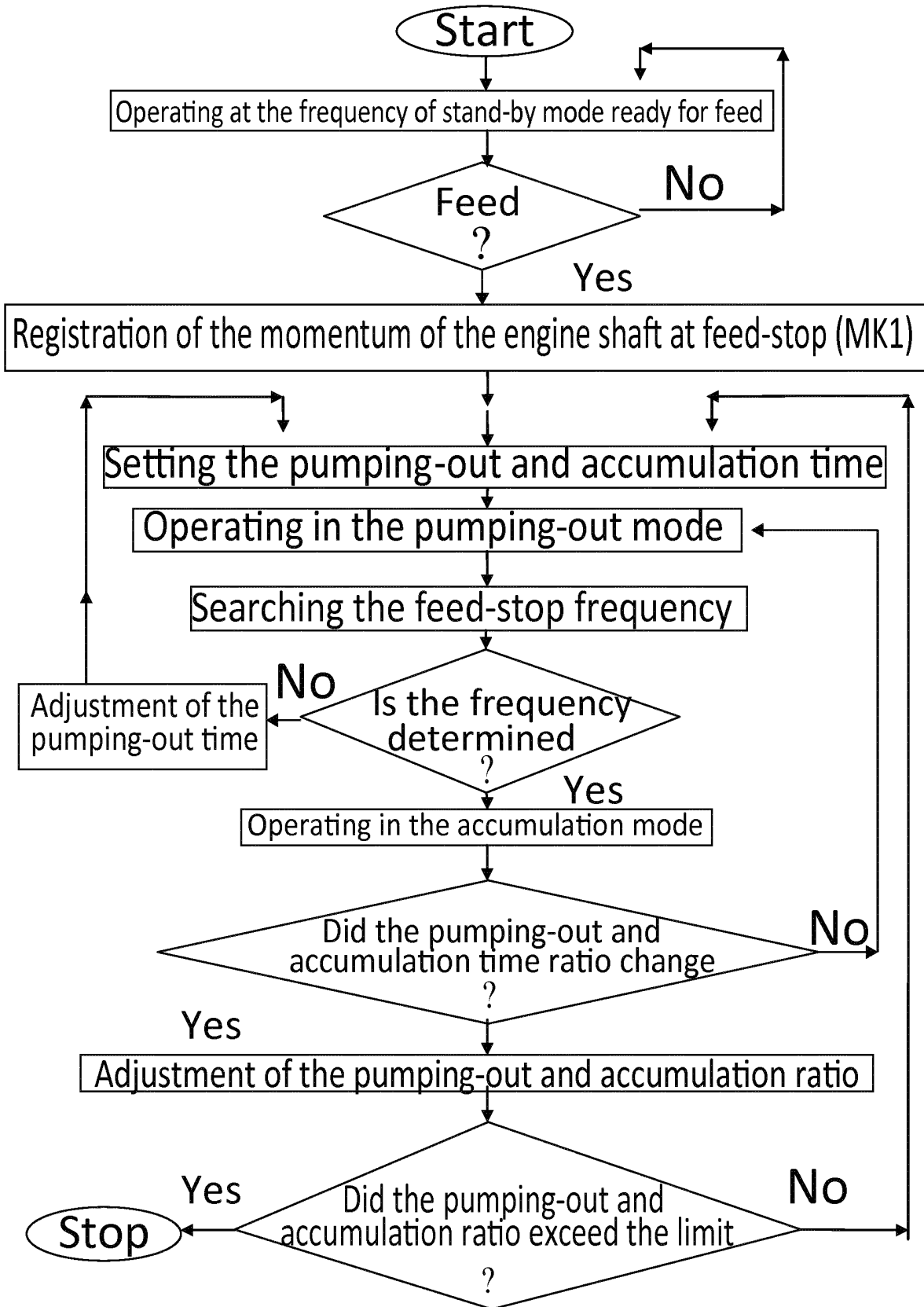


Fig. 2

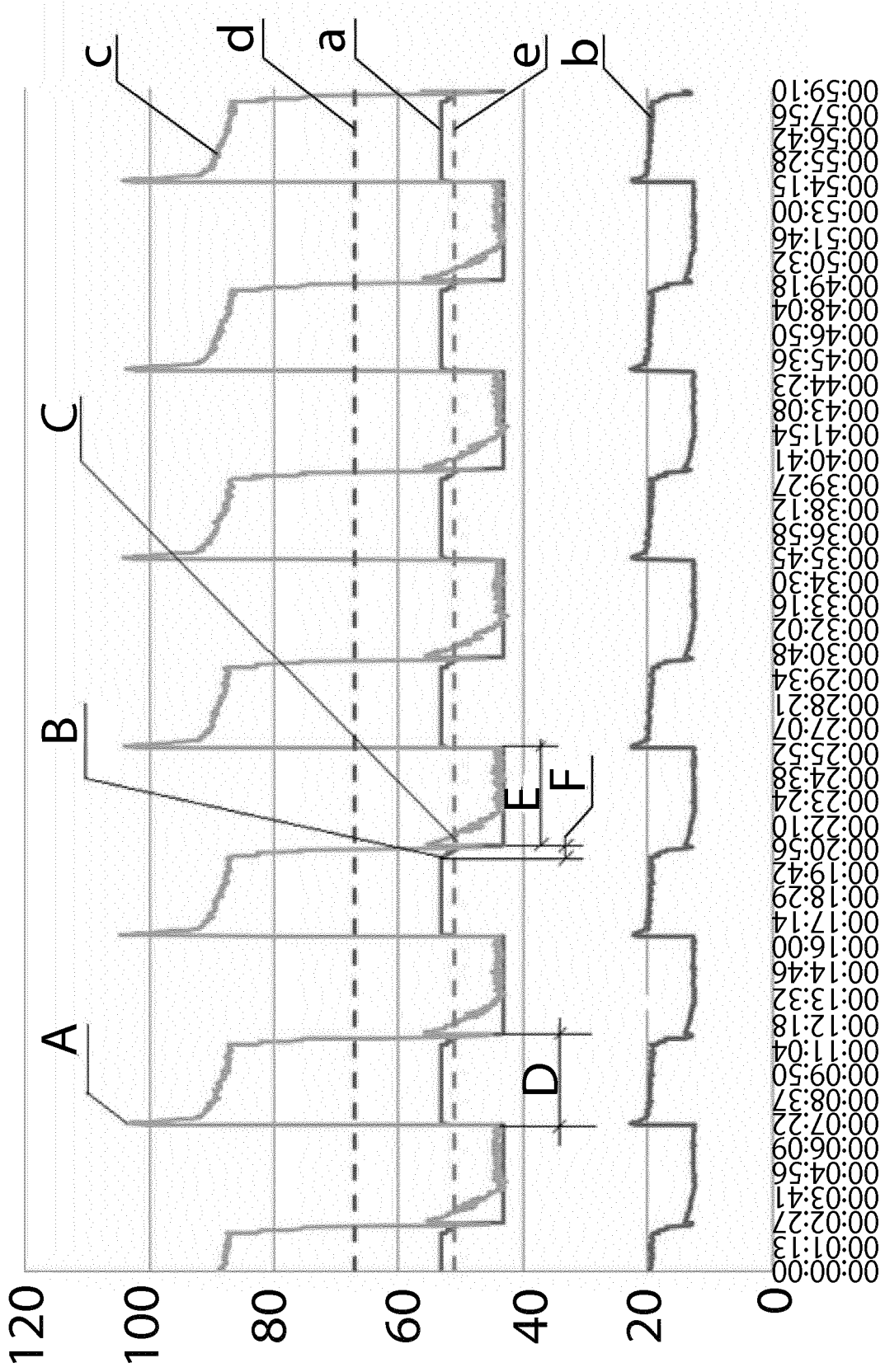


Fig. 3

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- US 2008247880 A [0002]
- RU 2119578 [0006]