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(54) **PROCESS AND DEVICE FOR GENERATING SIGNALS WHICH CAN BE TRANSMITTED IN A WELL**

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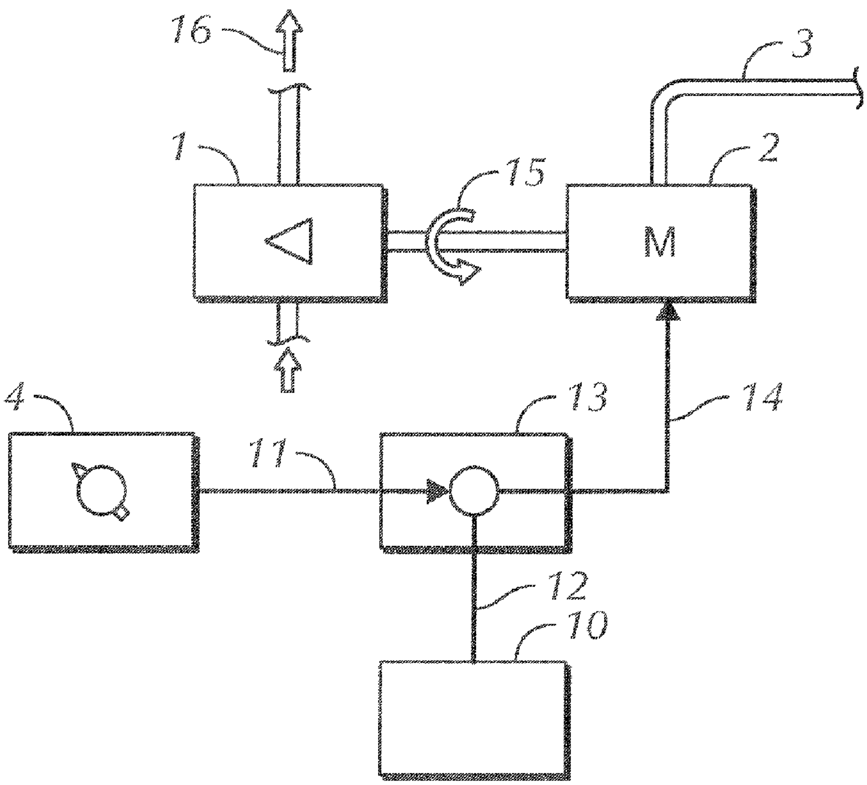
(57) **ABSTRACT**

In a process for generating signals which can be transmitted from above ground to a receiver located below ground in a well, the volume flow of a fluid pump (**1**) arranged above ground, which conveys fluid from a fluid tank (**8**) through the interior of a drill string to the bottom of a well, is temporally changed. The temporal change of the volume flow of the fluid pump (**1**) is caused by a change of the drive speed of the fluid pump (**1**), with the drive speed not falling below a minimum speed for maintaining a minimum volume flow.



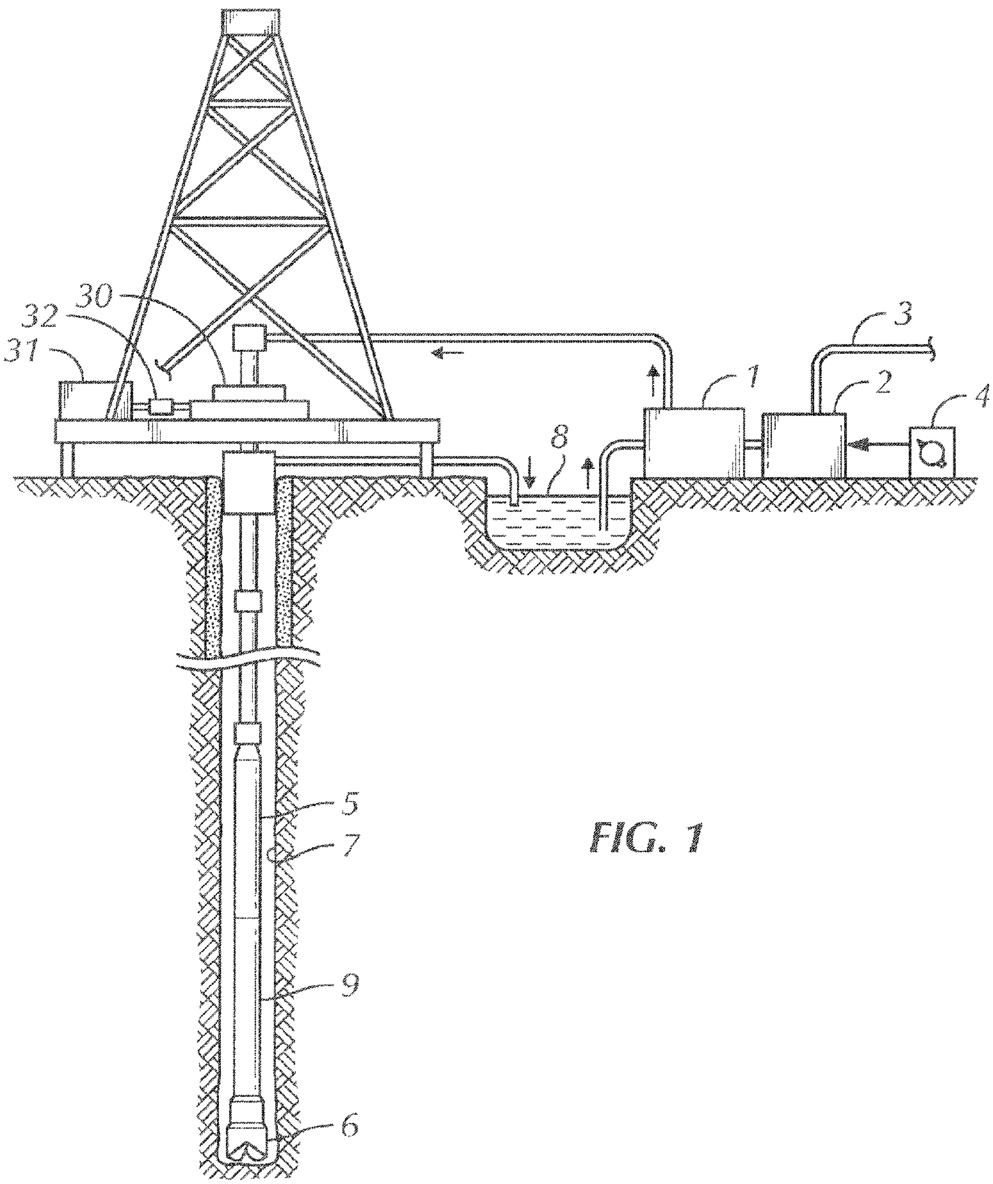



FIG. 1

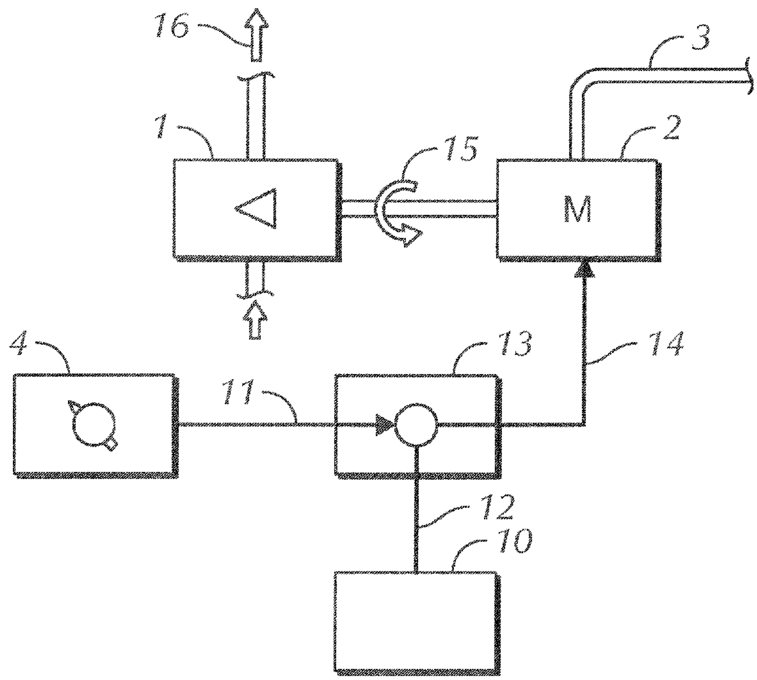



FIG. 2

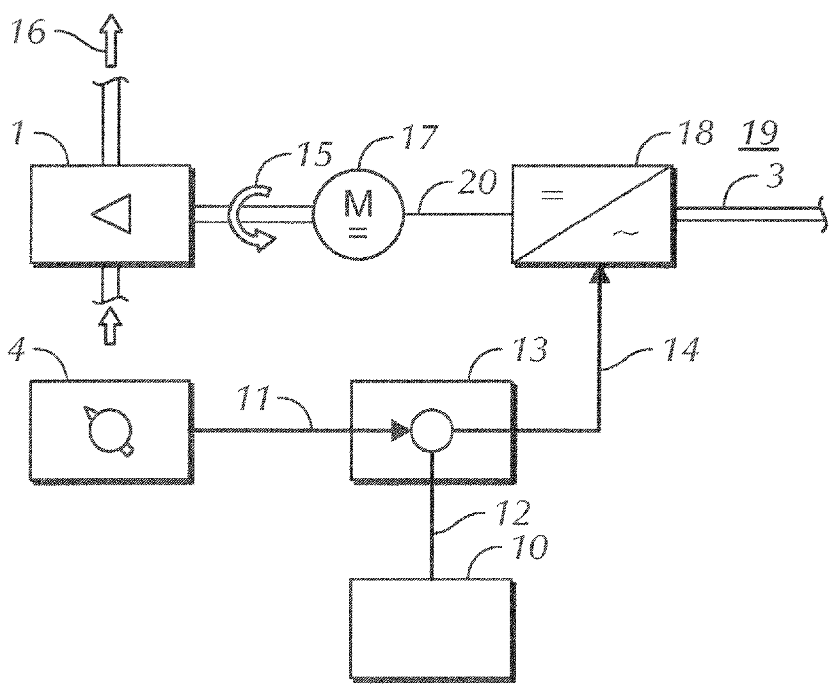



FIG. 3

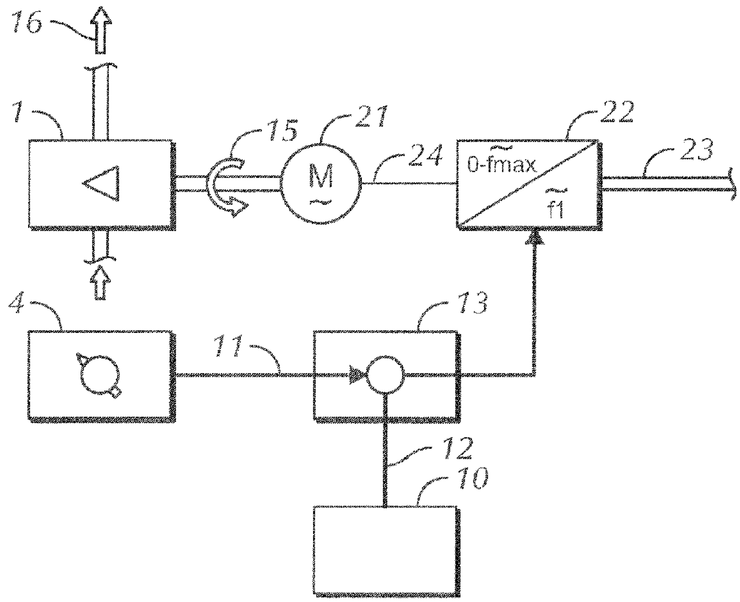

16
1
15
21
M
24
22
0-fmax
f1
23
4
11
13
12
10

FIG. 4

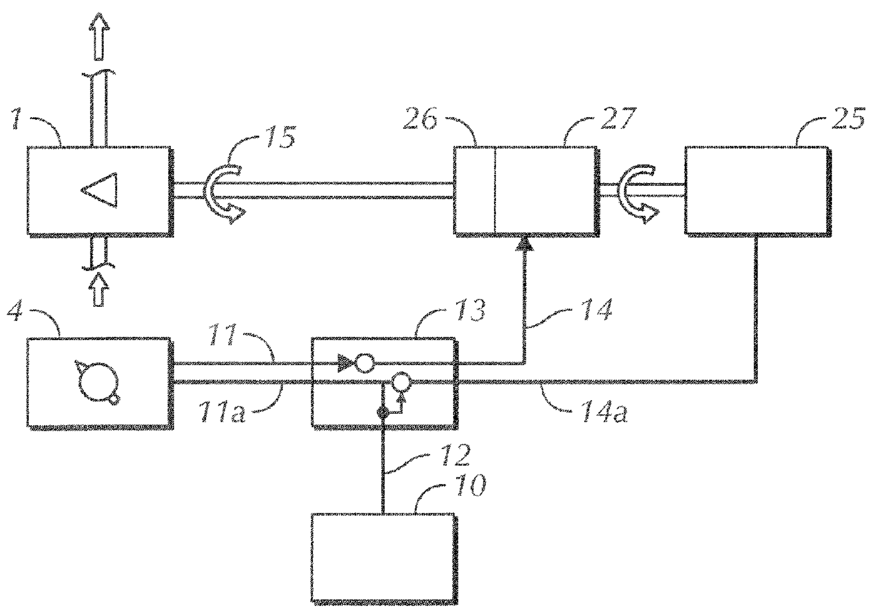

1
15
26
27
25
4
11
11a
13
14
14a
12
10

FIG. 5

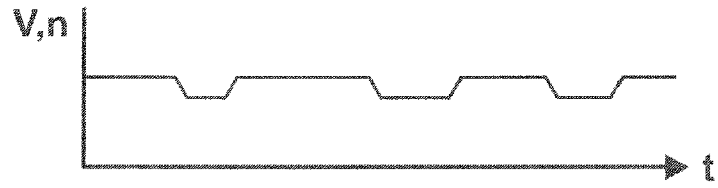



FIG. 6A

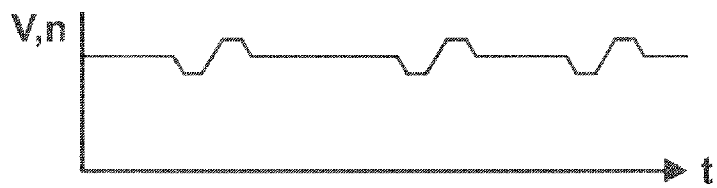



FIG. 6B

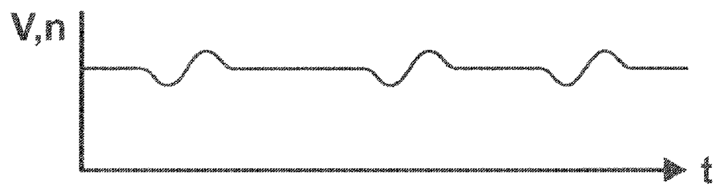



FIG. 6C

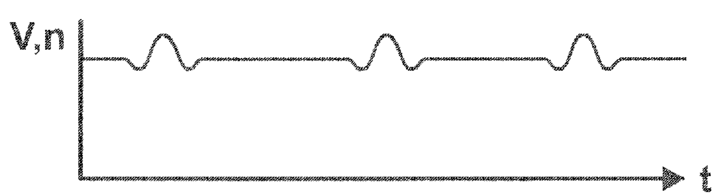



FIG. 6D

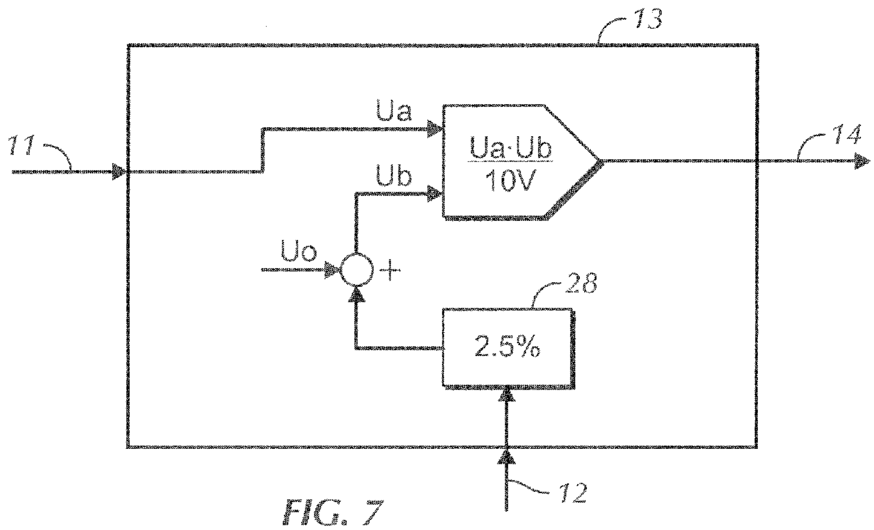



FIG. 7

# PROCESS AND DEVICE FOR GENERATING SIGNALS WHICH CAN BE TRANSMITTED IN A WELL

**[0001]** The invention relates to a process for generating signals which can be transmitted from above ground to a receiver located below ground in a well, wherein the volume flow of a fluid pump arranged above ground, which conveys fluid from a fluid tank through the interior of a drill string to the bottom of a well, is temporally changed. The invention furthermore relates to a device for executing this process.

**[0002]** In a process of the aforementioned type known from U.S. Pat. No. 5,332,048, the volume flow of the fluid generated by the fluid pump is changed by successively switching the fluid pump on and off. This process has, however, the disadvantage that it is time-consuming and requires an interruption to the drilling operation. There is also the risk that, during the interruption of the fluid current, cuttings may be deposited as a result of which the continuation of the drilling operation is impeded.

**[0003]** It is furthermore known from EP 0 744 527 B1, for transmitting information present above ground to an information receiver located below ground in a well during the drilling operation, to change the volume flow of the fluid generated by the fluid pump so that in a region downstream of the fluid pump a partial flow is diverted from the principal flow of the fluid pump and is returned into the fluid tank. This process is associated with significant energy losses, as, owing to the conveying height of the fluid pump, the diverted partial flow has a significant energy content which cannot be recouped at reasonable cost.

**[0004]** A process for signal generation by changing the volume flow of a fluid pump is known from U.S. Pat. No. 5,113,379, wherein a diverted partial flow of the volume flow conveyed by the fluid pump is received by a buffer reservoir and is then returned from this into the principal flow with the aid of a second pump. This process has the disadvantage that it requires significant equipment costs.

**[0005]** Furthermore, owing to the limited holding capacity of the buffer reservoir, only a very short volume flow change with limited amplitude can be achieved with this known process.

**[0006]** The object of the invention is to disclose a process of the aforementioned type which can be executed without interruption of the drilling operation, which does not cause any high energy losses and whose execution is possible with comparatively low equipment costs.

**[0007]** The object is achieved according to the invention by the process disclosed in claim **1** and by the device disclosed in claim **9**. Advantageous embodiments of the process and of the device are disclosed in the subclaims associated with these claims in each case.

**[0008]** According to the process according to the invention, the temporal change of the volume flow of the fluid pump is caused by a change of the drive speed of the fluid pump which does not fall below a minimum speed for maintaining a minimum fluid flow.

**[0009]** The process according to the invention is based on the knowledge that the volume flow of fluid pumps is substantially proportional to the pump speed. In order to achieve a temporal change of the volume flow of the fluid pump, it is thus only necessary to decrease or to increase the speed of the fluid pump in proportion to the required volume flow change. So that a signal, which is based on a change of the volume flow of the fluid pump, can still be received without errors below ground, a change of the volume flow is generally required, for instance, of 15% for a period of, for instance, **10** seconds. To generate a signal of this type it is thus sufficient to decrease the pump speed by 15% for the said period and then to increase the pump speed to the original value again. Speed changes of this type can be easily achieved with the conventional fluid pumps by controlling their drive accordingly. The required changes of the volume flow are also of a magnitude which can be achieved without significant disruption of the drilling operation.

**[0010]** The process according to the invention offers the opportunity to temporarily increase the pump speed after a reduction above the previously set normal value, in order to thus compensate for the volume flow loss caused by the reduction and to maintain on average a constant volume flow. A procedure of this type can be important for practical drilling reasons in order to prevent disruptions caused by inadequate transportation of the cuttings.

**[0011]** According to a further embodiment of the process according to the invention, the temporal changes of the pump speed and thus of its principal flow lie in frequency ranges below 1 hertz. This has the advantage that higher frequency telemetric signals are not distorted, so that transmission of signals of this kind via the drilling fluid in the drill string in the opposing direction, that is, from below ground to above ground is simultaneously possible. Furthermore, low frequency current changes with respect to the transmission ratios in the drill string are attenuated less strongly. The changes of the volume flow required to generate a signal which can be received without errors can thus be of less intensity.

**[0012]** Significant energy losses do not occur in the process according to the invention. The efficiency of conventional fluid pumps changes only slightly in the event of changes of the drive speed of a magnitude of up to 30%. The acceleration and deceleration of the moving masses also does not lead to significant losses, as the deceleration work helps to convey the fluid and relieves the drive of the fluid pump accordingly.

**[0013]** The invention will be described in more detail hereinafter with reference to the embodiments shown in the drawings, in which:

**[0014]** FIG. **1** shows a typical drilling rig,

**[0015]** FIG. **2** shows the general integration of a device for directly influencing the speed of the fluid pump,

**[0016]** FIG. **3** shows a version of a pump drive with a direct current motor with integration of the device for influencing the speed,

**[0017]** FIG. **4** shows a version of a pump drive with a three-phase alternating current motor with integration of the device for influencing the speed,

**[0018]** FIG. **5** shows a version of a pump drive with a diesel motor and a hydraulic torque converter with integration of the device for influencing the speed,

**[0019]** FIG. **6***a* to **6***d* show possible signal shapes of the generated telemetric signal and

[0020] FIG. **7** shows a possible electric embodiment of the integration of the signal for changing the speed.

[0021] FIG. **1** shows a typical rig for deep drilling. A fluid pump **1** is driven by an appropriate drive **2**. This can be electric or other motors, for example, diesel motors, with appropriate transmission devices. Accordingly, the required drive energy **3** can be supplied electrically or deriving from a combustible fuel. In order to generate the pumping rate required for drilling, that is, the required volume flow of fluid, the pump speed can be controlled via a desired value transmitter **4** acting electrically, hydraulically or pneumatically on the control unit of the drive **2**.

[0022] The fluid flow is pumped via the interior of the drill string **5** to the drill head **6** and flows into the annular chamber **7** back to the surface and from there into the reservoir tank **8**. For drilling, the drill string **5** is rotated by a rotary table **30** of a rotary drive, which is driven by a motor **31** via a coupling **32**. Alternatively, a fluid-driven well motor can also be provided at the drill head to drive the drill bit.

[0023] At the lower end of the drill string **5** there is a receiver **9** of a measuring and/or control device which is supposed to receive data from the surface and possibly transmits data to the surface itself, these signals being generated, for example via modulation of the fluid flow, as is known from many examples of deep drilling measuring devices with wireless data transmission.

[0024] FIG. **2** shows the fluid pump **1** with its drive **2** which, via a rotational movement with a defined speed, ensures that the pumping rate for the well required for drilling is generated. The required speed is adjusted via the desired value transmitter **4**. A signal generator **10** for generating signals, which can be transmitted to the below ground receiver **9**, changes the desired value **11** required for drilling with a control signal **12** in an interface **13** in such a way that desired value change **14** transmitted to the drive **2** controls the drive speed **15** of the fluid pump **1** in such a way that the temporal changes of the volume flow **16** of the fluid pump **1** required by the signal generator **10** result. The reciprocating pumps which are predominantly used with fluid pumps directly convert a speed change into a linearly proportional change of the volume flow, this volume flow change being accompanied by a pressure change acting in the same direction owing to the constant flow resistance of the overall system. The signal generator **10** can be, for example, a manually operable voltage divider, an analog curve shape generator or a computer, which generates the required modulation via software and emits said modulation via digital/analog conversion as electric analog voltage or directly as a digital signal.

[0025] FIG. **3** shows a concrete embodiment of a pump drive with a direct current motor **17** as can be found on many drilling rigs. The direct current motor **17** is fed via a direct current converter **18** which converts the drive energy **3** in the form of an electric alternating voltage **19** (typically, three-phase) into a direct voltage **20** with a controllable amplitude. The speed of the motor **17** is controlled by changing the direct voltage amplitude, which causes a linearly proportional regulation of the volume flow **16** of the fluid pump **1**. With the desired value transmitter **4**, typically for achieving the volume flow **16** required for drilling, an electric control signal is set as a desired value **11** (voltage e.g. 0 to 10 volts or current e.g. 4 to 20 mA or a digital desired value), said electric control signal controlling the output voltage of the direct current converter **18** (SCR=silicon controlled rectifier). For signal generation, the signal generator **10** changes the electric desired value **11** with a control signal **12** in the interface **13** in its percentage range in such a way that, owing to the desired value change **14**, the direct current converter **18** undertakes a change of the drive direct voltage for the motor **17** during the time of the required volume flow change, as a result of which the motor speed **15** and thus the volume flow **16** is synchronously modulated with the influenced desired value voltage **14**.

[0026] FIG. **4** shows a different conventional embodiment of a pump drive. A three-phase alternating current motor **21** is fed via a frequency converter **22** which converts the electric alternating current of a fixed frequency **23** (typically, three-phase) into an alternating current (typically, three-phase) with a controllable frequency **24**. The speed of the motor **21** is controlled by changing the frequency **24** of this alternating current, which causes a linearly proportional regulation of the volume flow **16** of the fluid pump **1**. With the desired value transmitter **4**, again for achieving the pumping rate required for drilling, the desired value **11** of an electric control signal is set (voltage e.g. 0 to 10 volts or current e.g. 4 to 20 mA or a digital desired value), said electric control signal controlling the frequency **24** of the supply voltage for the three-phase alternating current motor **21**. The signal generator **10** now changes this electric desired value **11** in the interface **13** in its percentage range in such a way that the frequency converter **22** undertakes a change of the frequency **24** of the motor supply voltage during the time of the required volume flow change, as a result of which the motor speed **15** and thus the volume flow **16** is synchronously modulated with the influenced desired value voltage.

[0027] FIG. **5** shows a further drive configuration for a fluid pump **1** to be found on drilling rigs. In this instance, a diesel motor **25** directly drives the pump **1** via an appropriate coupling **26** and a hydraulic converter **27** for speed regulation, without intermediate conversion of the mechanical energy into electric energy. Here, the speed **15** at the drive shaft of the pump required to achieve the volume flow required for drilling is achieved by controlling the speed of the diesel motor **25** or by controlling the hydraulic converter **27**. Regulation of the desired values **11** and **11***a* by the desired value transmitter **4** on the drilling platform is generally caused in this instance not electrically, but hydraulically or pneumatically. Accordingly, the interface **13** must convert the electric control signals **12** generated by the signal generator **10** into corresponding hydraulic or pneumatic signal changes. This is possible, for example, with the aid of electrically controlled proportional valves. The speed of the diesel motor and/or, if required, the hydraulic torque converter is now controlled with the desired values **14**, **14***a* influenced by the interface **13**.

[0028] FIGS. **6***a* to **6***d* show as examples different signal shapes which can be generated with the disclosed process and the disclosed devices. In the examples shown, a pulse code modulation is always shown as a modulation process. Here, the position of a "pulse", that is, a change of the volume flow V of the fluid pump **1** in the time t, defines the data content relative to a fixed reference time. However, analogously to the examples shown, any other modulation process can also be used, for example, amplitude modulation or a combination of a plurality of modulation processes.

[0029] The choice of which of the signal shapes shown as examples is used is defined inter alia by the transmission characteristics of the signal transmission path, the well with the drill string and by the reception properties of the receiver.

[0030] FIG. **6***a* shows a trapezoidal signal shape as a simple basic pattern. The pump speed n is decreased incrementally by several per cent, remains for some time at this reduced speed and then increases at the end of the signal back to the original desired value required for drilling.

[0031] In FIG. **6***b*, the signal shape of **6***a* is refined in such a way that the speed n or volume flow V reduced for some time is followed by a speed slightly above the desired speed for some time, so that on average volume flow V remains constant, which may be advantageous or necessary for drilling.

[0032] In FIG. **6***c*, the signal shape is further refined: it now has a sinusoidal shape. This signal shape has less harmonic distortion, as a result of which a possible telemetric connection in the opposing direction which operates on a higher frequency band is less distorted.

[0033] FIG. **6***d* shows a further signal shape with low harmonic distortion; it follows the time function sinus(x)/x, a function frequently used in signalling technology.

[0034] The signal shapes shown are to be understood as examples only. Virtually any signal shapes can be generated with the disclosed process and the disclosed device, so that the optimal shape can be selected depending on the given marginal conditions.

[0035] FIG. **7** shows as an example the concrete embodiment of an interface **13** with which the desired value **11** from the desired value transmitter **4** from FIG. **3** or **4** is modulated by a signal **12** of the signal generator **10**. In this instance, the desired value **11** required for drilling is an electric voltage between, for example, 0 and 10 volts, corresponding to the desired speeds 0 and n-max and the pumping rates 0 and Vmax. In this example, the modulation signal **12**, which is also present as electric voltage, should also be able to assume values between 0 and 10 volts, wherein at 5 volts the speed required by the desired value **11** should be transmitted without change, at 0 volts, the speed should be decreased by 20% and at 10 volts increased by 20%. With the elements shown, this function can be achieved by conventional electronics components, the modulation signal first being decreased by the factor 2.5 with a simple voltage divider **28** and then added to a fixed offset voltage U**0**, in this instance, 8V. This occurs, for example, with a simple operational amplifier stage.

[0036] The voltage Ub thus achieved is now linked to the original desired value voltage Ua according to the function (UaxUb)/10 in an analog multiplier stage, comprising, for example, the integrated switching circuit RC4200 with corresponding resistance wiring. The modulated output signal thus achieved then passes as a changed desired value **14** to the control unit of the pump drive, which generates the required speed from it. If, for example, the desired value **11** has a voltage of 7 volts corresponding to a required speed of 70% of n-max, the modulation signal **12** has a voltage of **10** volts, corresponding to a required increase of the speed of 20%, then the signal Ub is 10V/2.5+8V=12V. The multiplier stage generates 7V×12V/10V=8.4V from this, corresponding to 84% of n-max, that is, a 20% increase of the required speed of 70% of n-max. Here, the disclosed interface **13** is obviously shown in a simplified form; the concrete embodiment is, however, generally known from the prior art of semiconductor technology.

[0037] Analogously to this example, the interface **13** can, however, also be configured with control currents instead of with control voltages, with digital signals or with other physical (e.g. hydraulic or pneumatic) signals.

[0038] Instead of the multiplicative influence shown, an additive influence or a non-linear influence can also be produced if this is advantageous for operational reasons.

[0039] According to a further embodiment of the invention, an analog process for generating signals which can be transmitted from above ground to a receiver located below ground in a well comprises the temporal change of the speed of the drill string during rotary drilling. In the same way as disclosed above with respect to the modulation of the fluid flow for data transmission, a modulation of the rotational speed of the drill string during rotary drilling to generate signals which can be transmitted can also occur. In this instance, drive embodiments as disclosed above for pump drives can be developed analogously for rotary drives also. In many cases, the drive techniques for drill string rotary drives are identical to those of pump drives, it also being possible to use direct current motors, three-phase alternating current motors and diesel motors with corresponding traction elements. As a result, with the devices disclosed above, for example, with the deep drilling rig shown in FIG. **1**, the speed of the motor **31** and thus the angular velocity of the drill string **5** driven by the rotary table **30** can be temporally changed in such a way that the change is received below ground in the receiver by appropriate speed sensors. Single or multiple axis magnetometers or accelerometers, for example, are suitable as sensors of this kind.

**1**. A method for transmitting signals from above ground to a receiver located below: ground in a well, the method comprising:

temporarily changing the drive speed of an above-ground fluid pump that conveys fluid to a bottom of a well through an interior portion of a drill string, thereby changing the volume flow of the fluid pump;

wherein the change of volume flow comprises a signal detectable by the receiver located below ground in the well; and

wherein the drive speed is maintained above a minimum speed so as to maintain a minimum fluid flow.

**2**. The method of claim 1, wherein the temporary changes of the drive speed of the fluid pump are synchronized to maintain a constant average fluid flow.

**3**. The method of claim 1, wherein the temporary changes of the drive speed of the fluid pump have a frequency of less than **1** Hertz.

**4**. The method of claim 1 wherein the pump is a reciprocating pump.

**5**. The method of claim 1 wherein the pump is driven by an electric motor.

**6**. The method of claim 1 wherein the pump is driven by a diesel engine.

**7**. The method of claim 6 wherein the diesel engine speed is varied to change the drive speed of the pump.

**8**. The method of claim 6 wherein a hydraulic converter is used to change the drive speed of the pump.

**9**. A device for transmitting signals from above ground to a receiver located below ground in a well, the device comprising:

an above-ground fluid pump that conveys fluid to a bottom of a well through an interior portion of a drill string;

a value transmitter adapted to modulate a drive speed of the fluid pump, thereby changing the volume flow of the fluid pump, in response to a signal intended for transmission to the receiver located below ground in the well;

wherein the change of volume flow comprises a signal detectable by the receiver located below ground in the well; and

wherein the drive speed is maintained above a minimum speed so as to maintain a minimum fluid flow.

**10**. The device of claim 9, wherein the signal intended for transmission to the receiver located below ground in the well is generated by a manually operable voltage divider.

**11**. The device of claim 9, wherein the signal intended for transmission to the receiver located below ground in the well is generated by an analog curve shape generator.

**12**. The device of claim 9, wherein the signal intended for transmission to the receiver located below ground in the well is generated by a computer that generates the modulation via software.

**13**. The device of claim 12 wherein the computer emits said modulation as an analog signal.

**14**. The device of claim 12 wherein the computer emits said modulation as a digital signal.

**15**. The device of claim 9 wherein the pump is a reciprocating pump.

**16**. The device of claim 9 wherein the pump is driven by an electric motor.

**17**. The device of claim 9 wherein the pump is driven by a diesel engine.

**18**. The method of claim 17 wherein the diesel engine speed is varied to change the drive speed of the pump.

**19**. The method of claim 17 wherein a hydraulic converter is used to change the drive speed of the pump.

**20**. A device for transmitting signals from above ground to a receiver located below ground in a well, the device comprising:

an above-ground fluid pump that conveys fluid to a bottom of a well through an interior portion of a drill string; and

means for varying the speed of the fluid pump, thereby changing the volume flow of the fluid pump, whereby the changing volume flow comprises a signal to the receiver.

* * * * *