

CONTROL SYSTEM FOR A PUMP

Technical field of the Invention

5 The present invention relates generally to the field of pumps, and more specifically the present invention relates to pumps comprising variable frequency drive means. Furthermore, the present invention also relates to a method for operating such pumps.

10 Background of the Invention and Prior Art

Pumps comprising variable frequency drive means, such as sewage pumps, drainage pumps and de-watering pumps as well as submersible pumps, for example, are commonly used for pumping fluids in mining applications
15 such as in mining shafts, wells, at construction sites, or at other applications. Normally, submersible pumps are submersed, wholly or partly, during long periods of time both when they are in operation and when in an off-state.

A problem often encountered with pumps in general
20 and with submersible pumps in particular, is so called snoring operation, which means that the pumps sucks partly liquid and partly air. This is due to the fact that the liquid level has fallen below the required level of the pump causing the pump to start sucking partly air.
25 From this moment the pump is no longer productive and uses energy unnecessarily. Water silt remains in the mining shaft or in the well and particles will begin to settle and accumulate in the hydraulics of the pump. As long as the pump is in this snoring state, those particles remain at the hydraulics and cause extra wear on
30 the impeller, the suction cover, the seals, etc. This ineffective pumping contributes in a significant way to the increase of the overall operating costs of the pump. In addition, this snoring operation may damage the pump
35 motor due to overheating. In certain applications, in order to overcome this snoring problem, sensors, such as level switches, are used to sense the fluid level within the well. However, these level sensors may, for example,

be blocked or be subjected to a level shift due to a collision with subjects in the fluid such as a tree branch, and will thus in such a case deliver an erroneous signal.

5 US 6,481,973 to Struthers, present a pump system addressing a part of the abovementioned problem. Even though this pump system comprises variable frequency drive means it makes use of another control method to detect if the liquid level falls below a preset level, as
10 a complement to level switches. More precisely, this pump system detects if there is a sudden increase in the speed of the motor or a sudden drop of the motor torque. Said operation of the motor is monitored by a sensor connected to the AC output link extending from the variable
15 frequency drive means to the motor. However, this pump system embraces great disadvantages. In the case when the increase of the speed of the motor is slow, the system might not recognize the change as an indication of dry running of the pump. In another case, the pump system is
20 not able to detect if the water level is high enough for pump operation upon start of the pump, since in this state there cannot be a sudden increase of the speed of the motor or a sudden drop of the motor torque. Thereby, the pump will run for a considerable time until it is
25 switched off due to overheating, and the pump runs the risk of getting seriously damaged.

In many applications, such as the above-mentioned, the pump operates in a dynamic environment and thus the pump should be able to operate in an efficient way in
30 large range of head/pressure. The pump head corresponds to the height the pump, using a given power, is able to lift a given amount of liquid, for example, water, see Fig. 3 where a typical pump curve is indicated by the line 30. The degree of utilization of the power of the
35 pump may be reduced at low flows (Q). Thus, it would be an advantage to have a pump being able to pump at a high (or increased) degree of utilization of the power of the pump also at lower flows.

Another problem of frequent occurrence, especially when the pump has been in an off-state for quite a long period of time, is clogging of the intake and/or the impeller, which is caused mainly by particles in the fluid that sediment at the intake and in the impeller and build silt having a relatively thick or solid consistency. This, in turn, entails that a large starting torque of the pump motor is required in order to initiate the rotating of the pump impeller. Often a maximum starting torque is even required in order to start the rotation and the motor has to be operated at a maximum torque during a significant period of time. This consumes large amounts of energy and also wears the pump impeller and the motor. When the pump has been in an off-state for a long period even a maximum starting torque may not be enough and in such cases the pump has to be manually cleaned. In addition, a pump may also be clogged during running, for example, by particles sucked into the impeller. Thus, the reliability of pumps operated in such environments is low.

Abovementioned pump system according to US 6,481,973 to Struthers, is addressed to this problem as well. However, this method is erroneously directed to keep the motor running even if it is determined that the pump is clogged. More precisely, if an unacceptably high motor torque is detected for a given speed of the motor, the pump system will lower the speed of the motor and at the same time increase the level of acceptable motor torque. The aim is to get a stronger pump which is able to overcome the strength of the solid matter, but a stronger motor combined with a hard pollutant may lead to damages of the impeller, the impeller seat, the pump housing, etc.

Another known problem with pumps comprising conventional variable frequency drive means, is that the latter is usually mounted distant from the pump at a dry location above ground. More precisely, this necessitates a long power cable leading from the variable frequency

drive means to the motor of the pump, which for conventional variable frequency drive means can result in severe problems with electromagnetic interference. In abovementioned US 6,481,973 to Struthers, the variable frequency drive means is mounted within the pump casing, more precisely on a plate connected to the motor. However, the operation of the variable frequency drive means in this case is adversely affected by the heat emitted from the motor, which may lead to erroneous operation of the variable frequency drive means.

Thus, there is a need of an improved pump and an improved control method for controlling such a pump in an efficient way with respect to energy consumption and the durability of the pump.

Brief description of the invention

Embodiments of the present invention provide an improved pump, a pump system including such a pump, a computer program, a control device for such a pump and methods for controlling such a pump and pump systems in an efficient way with respect to pump capacity at varying pump head.

Embodiments of the present invention also provide an improved pump, a pump system including such a pump, a computer program, a control device for such a pump and methods for controlling such a pump and pump systems in an efficient way with respect to energy consumption.

Embodiments of the present invention further provide an improved pump, a pump system including such a pump, a computer program, a control device for such a pump and methods for controlling such a pump and pump systems in an efficient way with respect to durability of the pump.

Embodiments of the present invention provide an improved pump, pump system including such a pump, a computer program, a control device for such a pump and a method for controlling such a pump and pump

systems in a manner that reduces the wear of the pump and extends the pump life.

Embodiments of the present invention further provide an improved pump, pump system including such a pump, a computer program, a control device for such a pump and a method for controlling such a pump and pump systems in an environmental efficient way.

Embodiments of the present invention also provide an improved pump, pump system including such a pump, a computer program, a control device for such a pump and a method for controlling such a pump and pump systems in an efficient way with respect to start reliability as well as reliability" during operation.

Embodiments according to the present invention provide an improved pump, pump system including such a pump, a computer program, and methods for controlling such a pump and pump systems.

In the context of the present invention, the term "pump speed" is defined as the numbers of revolutions per time unit of the pump.

According to a first aspect of the present invention, there is provided a method for operating a pump comprising a motor and variable frequency drive means, the latter being arranged to control the operation of the motor by being connected to said motor and to a feeder cable of the pump, the variable frequency drive means comprising a rectifier, an inverter and a DC link extending therebetween, furthermore the pump is operatively connected to a control device. The method comprises the steps of:

- obtaining values of operating parameters of the pump indicating pump conditions, by means of sensing means, which is comprised as a part of said variable frequency drive means and which is operatively connected to said DC link,

- communicating said values of operating parameters from the variable frequency drive means to the control device,
- determining by means of the control device if a predetermined condition is fulfilled based on said obtained values of operating parameters, and
- communicating instructions from the control device to the variable frequency drive means, based on the fulfillment of said predetermined condition, in order to control the operation of the motor in accordance with said pump conditions.

According to a second aspect of the present invention there is provided a pump comprising a motor and variable frequency drive means, the latter being arranged to control the operation of the motor by being connected to said motor and to a feeder cable of the pump, the variable frequency drive means comprising a rectifier, an inverter and a DC link extending therebetween, furthermore the pump is operatively connected to a control device, **characterized** in that sensing means is comprised as a part of said variable frequency drive means, which sensing means is operatively connected to said DC link and which is arranged to obtain values of operating parameters of the pump indicating pump conditions, the variable frequency drive means being arranged to communicate to the control device said values of operating parameters, furthermore the control device is arranged to determine if a predetermined condition is fulfilled based on said obtained values of operating parameters and to communicate instructions to the variable frequency drive means, based on the fulfillment of said predetermined condition, in order to control the operation of the motor in accordance with said pump conditions.

According to a third aspect of the present invention, there is provided a computer program product loadable into a memory of a digital computer device, including software code portions for performing the method of

according to the first aspect of the present invention when the computer program product is run on the computer device.

According to a fourth aspect of the present invention, there is provided a pump system comprising a pump according to the second aspect of the invention, and further comprises an operator unit comprising input means and display means, which is adapted to present information related to the operation of the pump.

According to embodiments of the present invention, there is provided a control device for a pump according to the second aspect of the invention.

Thus, the present invention is based on the idea of obtaining values of operating parameters of the pump substantially continuously from the variable frequency drive means, which operating parameters indicate pump conditions and which are measured in an easy and inexpensive way and at the same time with high accuracy; and controlling the variable frequency drive means based on the obtained values of operating parameters, wherein the operation of the motor is adjusted in accordance with said pump conditions. Thereby, the pump is operated in an efficient way with respect to output capacity at varying flows, energy consumption and durability of the pump.

Moreover, since the wear of the pump parts such as the impeller and the seals is reduced, the pump life can be extended. Due to the fact that all information required for the control of the pump and pump motor and variable
5 frequency drive means is obtained from the variable frequency means, no external sensors are required.

According to a preferred embodiment of the present invention, the operating parameters may be: the DC link voltage of the variable frequency drive means, the DC
10 link current of the variable frequency drive means, the speed of the motor, or the like. By means of these operating parameters the power of the motor, the torque of the motor, or other suitable quantities may be determined.

15 In a preferred embodiment of the present invention, the event of dry running of the pump is determined based of the obtained values of operating parameters, e.g. the power of the motor at different motor speeds are compared with a predetermined reference value. If it is determined
20 that the power of the motor is lower than the predetermined reference level, the operation of the pump motor is stopped during a period of time having a predetermined length. Moreover, the motor is restarted when the predetermined period of time has expired and the same check is
25 performed once again until the predetermined condition is fulfilled. Thus, the snoring operation problem, which, as discussed above, causes extra wear of the pump, and in particular of the impeller, may cause the pump motor to overheat and also leads to unnecessary energy consumption,
30 tion, is dealt with and an efficient way of operating a pump comprising variable frequency drive means in respect of energy consumption and durability can thereby be obtained. Furthermore, the pump life can be extended owing to the fact that the wear of pump parts such as the im-
35 peller, seals and suction cover is significantly reduced.

In an alternative embodiment of the present invention, the power of the motor is maintained at a substantially constant level. The obtained operating parameter

value is compared with a predetermined reference level of the operating parameter; if the operating parameter value is lower than the predetermined reference level, the speed of the motor required to obtain the predetermined power level is calculated; and the pump is ran at the calculated speed. Preferably, the calculated speed is compared with a preset maximum allowed speed of the pump; and if the calculated speed is higher than the preset maximum speed of the pump, the pump is ran at the preset maximum speed. Thus, the problem of maintaining a high degree of utilization of the power of the pump over a large range of flows is dealt with. As is shown in fig. 3 by line 32, the pump head/pressure can be increased by 20% to 30% by means of the method according to said second aspect. Thus, by increasing the speed of the motor the pump will reach a higher pump head at lower flows than a conventional pump. Hence, an efficient way of operating a pump comprising variable frequency drive means in respect of pump capacity at varying pump head is obtained.

According to an another embodiment of the present invention, a detection whether the pump is clogged is performed; and if it is detected that the pump is clogged, the pump is ran reversely at a predetermined speed during a period of time having a predetermined length. Thereafter the pump is stopped and started in the normal direction. Moreover, the step of running the pump impeller reversely, stopping it and change the operating direction is repeated until it is detected that the clogging condition has ceased. Thus, the problem of clogging or jam of the intake and/or pumping house, which may be caused by particles in the fluid that sediment at the intake and at the impeller and build silt having a relatively thick or solid consistency, is dealt with. Owing to the fact that pump runs backwards and forward again in a repeated manner, the clogging can be removed in an efficient way. Thereby the starting reliability can be increased. In addition, this embodiment provides for an

efficient way of operating a pump comprising variable frequency drive means in respect of energy consumption and durability since the wear of, especially, the pump impeller is reduced. Moreover, since the clogging condition can be removed in an efficient way the energy consumption of the pump can also be reduced.

As realized by the person skilled in the art, the method according to the present invention, as well as preferred embodiments thereof, are suitable to realize or implement as a computer program or a computer readable medium, preferably within the contents of a control device or a processing means of a pump or a pump system.

The features that characterize the invention, both as to structure and to method of operation, together with further objects and advantages thereof, will be better understood from the following description read in conjunction with the accompanying drawings. It is to be expressly understood that the drawings is for the purpose of illustration and description and is not intended as a definition of the limits of the invention. These and other objects attained, and advantages offered, by the present invention will become more fully apparent as the description that now follows is read in conjunction with the accompanying drawings.

Brief description of the drawings

Above-mentioned and other features and advantages of the present invention will be apparent from the following detailed description of preferred embodiments, merely exemplifying, in conjunction with the attached drawing, wherein:

- Fig. 1 schematically shows an embodiment of a pump according to the present invention;
- Fig. 2 schematically shows an embodiment of a pump system according to the present invention;

- Fig. 3 shows a pump curves for a conventional pump and a pump operated in accordance with the present invention;
- Fig. 4 shows the principles of a method of an embodiment according to the present invention;
- Fig. 5 shows the principles of a method of another embodiment according to the present invention;
- Fig. 6 shows the principles of a method of yet another embodiment according to the present invention;
- Fig. 7 schematically shows a further embodiment of a pump and a control device for such a pump according to the present invention;
- Fig. 8 schematically shows another embodiment of a pump and a control device for such a pump according to the present invention; and
- Fig. 9 schematically shows yet another embodiment of a pump and pump system according to the present invention.

Detailed description of preferred embodiments of the Invention

In the following, there will be disclosed preferred embodiments of a method for operating a pump and a pump system.

- With reference first to Fig. 1, a first embodiment of a pump according to the present invention will be described. For purpose of illustration, the embodiments of the present invention described hereinafter are utilized in present submersible pumps comprising variable frequency drive means. But, as the skilled man within the art easily realizes, the present invention can also be utilized in other types of pumps, such as sewage pumps, drainage pumps, de-watering pumps, etc.

- The submersible pump 1 of Fig. 1 comprises a variable-speed unit 2, preferably variable frequency drive means (VFD unit) connected via a connection cable 3 to a power source (not shown) delivering, for example, a single phase voltage or a three phase voltage. Unlike

prior art pumps comprising a VFD unit, which are only designed to receive a power supply within the range from approximately 200 V to approximately 250 V, the pump 1 according to the present invention is able to receive a power supply within the range from approximately 90 V to approximately 250 V. Thereby, the inventive pump 1 may be used both in countries/regions having a standard power supply of approximately 110 V and in countries/regions having a standard power supply of approximately 230 V.

10 Thereto, prior art pumps are designed to be supplied with electricity having a frequency of 50 Hz or 60 Hz, which are known standards for different countries and/or different regions in a country. However, the inventive pump is designed to be used in many different countries, i.e. the input frequency may be at least within the range of 50-60 Hz, but in reality the inventive pump may cope with which ever frequency available. Thus, a given pump may be used connected to many different power mains, i.e. a given pump is a globally usable pump ready to be put into operation.

The VFD unit 2 comprises an electromagnet interference filter 4 (EMI filter) arranged at the connection cable 3 in order to filter out electromagnet interference at the input. The connection cable 3 is connected to a feeder cable of the pump 1. The EMI filter 4 is connected to a rectifier 5, which in turn is connected via a DC link 10, including a capacitor 6, to a transducer or inverter 7. The inverter 7 converts the DC current to a three-phase current, which is supplied to a pump motor 9 via a connection 8. The function and components and parts of a VFD unit 2 is well-known for the man skilled within the art and hence they will not be described in further detail herein.

It is important that the VFD unit 2 is mounted thermally shielded from the motor 9 and at the same time mounted in a thermally conductive arrangement with the pumped fluid, such that the temperature of the VFD unit 2

is kept at a low level during operation, which eliminates a source of error.

A control device 11 is arranged operatively connected to the pump 1 and in communication with the VFD unit 2 via a communication bus (not shown) and controls or drives the pump 1, e.g. to increase or decrease the speed of the motor 9 in order to pump a larger or a smaller amount of liquid, for example, water. Further, the VFD unit 2 comprises sensing means 16, which is operatively connected to said DC link 10 and which is arranged to obtain values of operating parameters of the pump 1 indicating pump conditions.

The VFD unit 2 is arranged to communicate to the control device 11 said values of operating parameters, which, according to a preferred embodiment of the present invention, may be: the DC link voltage, the DC link current, the speed of the motor, or the like. By means of these operating parameters the power of the pump 1 or of the motor 9, the torque of the motor 9, or other suitable quantities may be determined. The control device 11 is arranged to determine if a predetermined condition is fulfilled based on said obtained values of operating parameters and to communicate instructions to the VFD unit 2, based on the fulfillment of said predetermined condition, in order to control the operation of the motor 9 in accordance with said pump conditions.

The control device 11 is, in turn, controlled by processing means 12, which includes storing means 13. The storing means 13 may include a random access memory (RAM) and/or a non-volatile memory such as read-only memory (ROM). In this embodiment, the storing means 13 comprises a computer program 14 comprising instructions for bringing a computer or a microprocessor, such as the processing means 12, to cause method steps in accordance with the present invention. As will be appreciated by one of ordinary skill in the art, storing means may include various types of physical devices for temporary and/or persistent storage of data which includes solid state,

magnetic, optical and combination devices. For example, the storing means may be implemented using one or more physical devices such as DRAM, PROMS, EPROMS, EEPROMS, flash memory, and the like.

5 With reference now to fig. 2, an alternative embodiment of the present invention will be described. In this embodiment, the control device 11 is arranged in communication via an interface unit (not shown) with an operator unit 22 including input means in the form of a
10 keyboard 24, which allows the operator to input, for example, control commands, and a display means or screen 26 for presenting information related operation of the pump, for example, time history of the operating parameters, or status information of the pump. In one embodiment,
15 the operator unit 22 is a personal computer. The communication link between the pump 1 and the operator unit 22 can be a wireless link or a hard wired link. Furthermore, the operator unit 22 can, in turn, be connected to a communications network, such as the Internet.
20 By means of the operator unit 22, the operator is capable of monitoring the operation of the pump as well as different operating parameters associated to the operation thereof via the display 26. According to another embodiment, the display is a touch sensitive screen and
25 in this case a number of soft-keys can be arranged on the screen in order to present different commands at different presented interfaces on the display 26. Furthermore, the operator unit may comprise storing means (not shown), which, in turn, may include a random access memory (RAM)
30 and/or a non-volatile memory such as read-only memory (ROM). As will be appreciated by one of ordinary skill in the art, storing means may include various types of physical devices for temporary and/or persistent storage of data which includes solid state, magnetic, optical and
35 combination devices. For example, the storing means may be implemented using one or more physical devices such as DRAM, PROMS, EPROMS, EEPROMS, flash memory, and the like.

Running data of the pump 1, such as operating parameters like running time, number of starts, energy consumption, and alarm data, as well as service record can be obtained and stored in a logging file in the storing means 13. The logging file can be presented for an operator by means of the operator unit 22. Moreover, the logging file can be downloaded to the operator unit 22 for, e.g. storage.

Of course, there are a number of conceivable designs of the control device 11, for example, the control device can be realized by means of a processor including, inter alia, programmable instructions for executing the methods according to the present invention. According to another embodiment, the control device is implemented in the form of a micro-chip or the like data carrier comprising software adapted to execute the functions described above and hereinafter. Furthermore, in Figs. 7-9 alternative embodiments of the present invention are shown. Like or similar parts and/or devices in Figs. 1, 2 and 7-9 are being denoted with the same reference numerals. In Fig. 7, the control device 11, which may be encapsulated in a hermetically sealed housing, is arranged on an outer surface of the pump housing. The control device 11 can be attached or fixed at the housing in a number of ways. For example, the device 11 can be fixed by means of screws. In Fig. 8, the control device 11 is in form of a plug-in unit adapted to be inserted in a control device receiving recess 15. In Fig. 9, the control device 11 is arranged in the control panel 22.

With reference now to Fig. 4, the general principles of the method for operating a pump according to a first aspect of the present invention will be described. This first aspect of the method according to invention deals with the snoring operation problem or the dry running operation problem, which, as discussed above, entails increased wear of pump part such as the impeller and the seals, may cause the pump motor to overheat and also leads to that unnecessary energy is consumed. In

addition, pump motors are designed to provide optimum performance when they are pumping and operating in liquid, so prolonged dry running operation can damage the pump motor. Thus, the first aspect of the invention provides for a an efficient way of operating a pump 1 comprising a VFD unit 2, as described with reference to any one of Figs. 1-2 and 7-9 in respect of energy consumption, pump life, and durability.

First, at step 40, the operation of the pump is initiated, i.e. the pump is started. Then at steps 42 and 44 it is determined if a predetermined condition is fulfilled. For example, at step 42, the pump is operated at a first speed level for a predetermined period of time and at a second speed level for a predetermined period of time. Preferably, said first speed level and said second speed level are low speed levels. For each speed level, the power of the motor 9 is determined and thereafter, at step 44, it is checked whether the relation between the speed of the motor 9 and the power of the motor is approximately a cubic function (if the power of the motor is proportional to the cube of the speed of the motor) using the two speed levels and the resulting power from each one of them. If the relation is a cubic function, the pump can be ran in normal operation and if the relation is not a cubic function it is an indication that the pump 1 pumps air and it is determined that the liquid level is too low and the pump cannot be ran at the desired speed level. This determination is performed in the control device 11, e.g. in the processing means 12. It shall be pointed out that the relationship between the speed level and the resulting power not necessarily has to be cubic, other exponents may be appropriate for other mixtures of fluids, i.e. liquids and gases.

If, in step 44, it is determined that the liquid level is not sufficient, the algorithm proceeds to step 46, where the control device 11 sends instructions to the VFD unit 2 to stop/pause the operation of the pump during a predetermined time period, e.g. a number of minutes,

maybe about 2 minutes. When this period of time has expired, the algorithm returns to step 42.

On the other hand, if, at step 44, it is determined that the liquid level is sufficient, the algorithm proceeds to step 48, where the speed of the pump 1 is
5 increased to a desired speed. Thus, the pump 1 is now operated in a normal manner.

In order to avoid the snoring operation it is checked substantially continuously that the pump 1 does
10 not pump air during operation. Therefore, at step 50, it is checked whether the liquid level still is sufficient, i.e. whether the pump 1 sucks air partly or mainly or if it is pumping liquid, by determining if a second predetermined condition is fulfilled. This is performed on a
15 substantially continuous basis. In order to perform this check, a value of a suitable operating parameter is obtained by the sensing means 16 of the VFD unit 2, which value is communicated to the control device 11. For example, the DC link voltage, the DC link current, or the
20 like can be used directly or can be used to determine, for example, the torque of the motor 9 or preferably the power of the motor 9. A sudden drop of the power of the motor 9 during operation indicates that the pump 1 pumps air instead of liquid.

For example, the second condition is a comparison
25 between the power of the motor 9, for example, and a predetermined reference level, which may be stored in the storing means 13, and if the power of the motor is lower than the predetermined reference level, it is determined
30 that the liquid level is too low. Preferably, the predetermined level may be about 70% of the maximum power of the motor for the present speed of the motor 9. Alternatively, a step comparable to step 42 may be performed at a regular basis between step 48 and step 50, in order to
35 determine if liquid is present at the inlet of the pump 1.

If it is determined that the liquid level at the inlet of the pump is sufficient, i.e. the power of the

motor 9 is higher than the predetermined level, the algorithm returns to step 48. On the other hand, if it is determined that the fluid level at the inlet of the pump is too low, i.e. the power of the motor is lower than the predetermined level, the algorithm instead proceeds to step 52, where the operation of the pump is stopped. Subsequently, the algorithm proceeds to step 46, where the operation of the pump is kept stopped during a predetermined period of time. When this pause period has expired, the algorithm proceeds to step 42.

With reference now to Fig. 5, the general principles of the method for operating a pump according to a second aspect of the present invention will be described. This second aspect of the method according to invention deals with the problem of maintaining the power of the pump at a substantially constant level over a large range of flows. As is shown in fig. 3 by line 32, the pump head/pressure can be increased by 20% to 30% by means of the method according to the second aspect. The power of the pump is kept at a substantially constant level at varying pump head by adjusting the speed of the motor. Due to the fact that the pump is operated more efficient at low flows a smaller pump can be used to pump a given amount of liquid, and the wear of the pump can also be reduced. The inventive pump is an universally usable pump which is designed to be used in many different applications having varying demands. A high pump capacity may be achieved for a given pump for varying pump head by adjusting the speed of the motor. Thus, the second aspect of the invention provides for a an efficient way of operating a pump comprising a VFD unit 2 as described with reference to any one of Figs. 1-2 and 7-9 in respect of energy consumption and durability.

First, at step 60, the operation of the pump 1 is initiated, i.e. the pump 1 is started. Then, at step 62, the pump is ran at a desired speed level. An operating parameter of the pump is monitored substantially continuously and values corresponding to the operating parameter

are obtained by the sensing means 16 of the VFD unit 2, which value is communicated to the control device 11. For example, the DC link voltage, the DC link current, or the like can be used directly or can be used to determine, for example, the torque of the motor 9 or preferably the power of the motor 9. At the control device 11 the power of the motor 9, for example, is compared with a predetermined reference level at step 64, e.g. the rated power of the motor 9, which may be stored in the storing means 13, in, for example the processing means 12. If, at step 64, it is determined that the power level of the motor is higher than the predetermined reference level, the algorithm returns to step 62, and the operation of the pump is maintained at said desired speed level. On the other hand, if it is determined that the power level of the motor is lower than the predetermined level, the algorithm proceeds to step 66, where the speed required to reach the predetermined power level of the motor is calculated in the processing means 12.

Thereafter, at step 68, the calculated speed is compared with a preset maximum speed. If the calculated speed is found to be higher than the preset maximum speed, the algorithm proceeds to step 70, where the control device 11 communicates instructions to the VFD unit 2 to run the motor 9 at the preset maximum speed, and the algorithm returns to step 64. If it is found that the calculated speed is lower than the preset maximum speed, the algorithm proceeds to step 72 and the control device 11 communicates instructions to the VFD unit 2 to run the motor 9 at the calculated speed. Thereafter, the algorithm proceeds to step 64 where the procedure is continued. By maintaining the power of the motor at a substantially constant level, the head/pressure can be increased at low flows as indicated by means of line 32 in fig. 3.

Turning now to fig. 6, the general principles of the method for operating a pump according to a third aspect of the present invention will be described. This third

aspect of the method according to invention deals with the problem of clogging or jam of the intake and/or the impeller of the pump 1, which may be caused by particles in the fluid that sediment at the intake and in the
5 impeller and build silt having a relatively thick or solid consistency. Thus, a large starting torque of the pump motor is required in order to initiate the rotating of the pump impeller. This consumes large amounts of energy and also wears the pump impeller and the motor.

10 When the pump has been in an off-state for long period even a maximum starting torque may not be enough and in such cases the pump has to be manually cleaned, and, consequently, the starting reliability of pumps operated in such environments will be low. Thus, the third aspect
15 of the invention provides for a an efficient way of operating a pump comprising a VFD unit 2 as described with reference to any one of Figs. 1-2 and 7-9 in respect of energy consumption, durability and starting reliability.

20 First, at step 80, the operation of the pump 1 is initiated, i.e. the pump 1 is started. Then, at step 82, the pump is ran at a desired speed level. Thereafter, at step 84, a check is performed whether the pump is clogged/jammed. This can as an example be performed in
25 the following two ways. One way is to measure an operating parameter of the pump and compare it with a predetermined reference level, for example, determine the power of the motor 9 and comparing it with a predetermined reference level of the power of the motor 9, for
30 example, the rated power of the motor 9. If the measured power of the motor is higher than this predetermined reference level, it is an indication of a clogged/jammed condition. The second way is to monitor an alarm function of the variable frequency drive means 2 and an alarm
35 indicating DC link over-current is used as an indication of a clogged/jammed condition.

If it, in step 84, is determined that the pump 1 is not clogged, the algorithm returns to step 82, where the

operation of the pump 1 is maintained. On the other hand, if it is determined that the pump 1 is clogged, the algorithm proceeds to step 86, where the control device 11 communicates instructions to the VFD unit 2 to drive the impeller reversely at a first speed during a predetermined period of time. After the predetermined period of time the pump 1 is stopped and then ran in a forward rotating direction again. Preferably, such a cycle lasts about 1-10 seconds. Then, at step 88, it is checked whether the clogging state has ceased, as is performed at step 84 above. If not, the procedure returns to step 86. This cycle is repeated until the clogging condition has been removed. If the clogging state has ceased, the algorithm returns to step 82.

In order to prevent clogging during normal operation of the pump 1, the following procedure can be performed at regular intervals: running the pump 1 reversely at a predetermined speed during a period of time having a predetermined length, stopping the pump 1 after said period and running the pump 1 at its normal rotation direction. Thereby, the operational reliability of the pump can be improved still more.

Reference is now made to fig. 3. The lines shown at reference numbers 30 and 32 are examples of liquid flow and head ratio for a certain pump 1, which is supplied with a 3 phase voltage having a frequency of 60 Hz from the VFD unit 2. 60 Hz is the standard frequency in some countries in the power mains, but by means of the VFD unit 2, this level may be increased considerably, e.g. up to 150 Hz, and by doing so said lines 30, 32 will be more or less offset in an direction upwards in the chart of fig. 3, and a certain pump may be used for very fluctuating applications and conditions.

Feasible modifications of the present Invention

Although specific embodiments have been shown and described herein for purposes of illustration and exemplification, it is understood by those of ordinary skill

in the art that the specific embodiments shown and described may be substituted for a wide variety of alternative and/or equivalent implementations without departing from the scope of the invention. Those of
5 ordinary skill in the art will readily appreciate that the present invention could be implemented in a wide variety of embodiments, including hardware and software implementations, or combinations thereof. As an example, many of the functions described above may be obtained and
10 carried out by suitable software comprised in a micro-chip or the like data carrier. This application is intended to cover any adaptations or variations of the preferred embodiments discussed herein. Consequently, the present invention is defined by the wording of the
15 appended claims and equivalents thereof.

AMENDED CLAIMS

[received by the International Bureau on 18 October 2006]

(18.10.2006)]

1. A method for operating a pump, comprising a motor and variable frequency drive means, the latter being arranged to control the operation of the motor by being connected to said motor and to a feeder cable of the pump, the variable frequency drive means comprising a rectifier, an inverter and a DC link extending therebetween, furthermore the pump is operatively connected to a control device, the method being **characterized** by the steps of:

- obtaining values of operating parameters of the pump indicating pump conditions, by, means of sensing means, which is comprised as a part of said variable frequency drive means and which is operatively connected to said DC link,
- communicating said values of operating parameters from the variable frequency drive means to the control device,
- determining by means of the control device if a predetermined condition is fulfilled based on said obtained values of operating parameters, and
- communicating instructions from the control device to the variable frequency drive means, based on the fulfilment of said predetermined condition, in order to control the operation of the motor in accordance with said pump conditions.

2. The method according to claim 1, wherein the step of obtaining values of operating parameters of the pump comprises the step of:

- obtaining values of at least one of the following operating parameters: the DC link voltage level, the DC link current level, the torque of the motor, or the power of the motor.

3. The method according to claim 1 or 2, furthest comprising the step of:

- detecting a certain pump condition by using said at least one operating parameter.

4. The method according to claim 3, wherein said pump condition concerns the presence of liquid at an inlet of the pump.

5. The method according to claim 4, wherein the step of determining if a predetermined condition is fulfilled comprises the steps of:

- running the pump at a first speed level for a predetermined period of time,
- running the pump at a second speed level for a predetermined period of time, and
- determining if the power of the motor is proportional to the cube of the speed of the motor, based on the values of operating parameters obtained by the sensing means for the first speed level and the second speed level, respectively.

6. The method according to any of the claims 4-5, wherein the communicated instructions from the control device to the variable frequency drive means, are

- run the pump at a desired speed level, if it is determined that the predetermined condition is fulfilled, or
- stop the operation of the pump a predetermined period of time, if it is determined that the predetermined condition is not fulfilled.

7. The method according to claim 6, further comprising the steps of, if the pump is ran at the desired speed level:

- checking the presence of liquid at an inlet of the pump by,

- obtaining values of operating parameters of the pump, by means of the sensing means,
- communicating said values of operating parameters from the variable frequency drive means to the control device,
- determining by means of the control device if a second predetermined condition is fulfilled based on said obtained values of operating parameters, and
- communicating instructions from the control device to the variable frequency drive means, based on the fulfilment of said second predetermined condition, in order to control the operation of the motor.

8. The method according to claim 7, wherein the step of determining if a second predetermined condition is fulfilled comprises the step of:

- comparing the obtained values of operating parameters with a predetermined reference level.

9. The method according to any of claims 7-8, wherein the communicated instructions from the control device to the variable frequency drive means, are

- run the pump at the desired speed level, if it is determined that the second predetermined condition is fulfilled, and
- stop the operation of the pump a predetermined period of time, if it is determined that the second predetermined condition is not fulfilled.

10. The method, according to claim 2, further comprising the step of:

- maintaining the value of the at least one operating parameter at a substantially constant level.

11. The method according to claim 10, wherein the step of determining if a predetermined condition is fulfilled comprises the steps of:

- running the pump at a desired speed level,
- determining if the power of the motor is lower than a predetermined reference level of the power of the motor, based on the values of the power of the motor obtained by the sensing means for the desired speed level.

12. The method according to any of the claims 10-11, wherein the communicated instructions from the control device to the variable frequency drive means, are

- run the pump at the desired speed level, if it is determined that the predetermined condition is not fulfilled, or
- calculate the speed of the motor required to reach a predetermined reference level of the power of the motor, if it is determined that the predetermined condition is fulfilled, and
- run the pump at said calculated speed.

13. The method according to claim 12, further comprising the steps of, if the pump is ran at the calculated speed:

- comparing the calculated speed of the pump with a preset maximum speed of the pump, and
- run the pump at said calculated speed, if the calculated speed is lower than the preset maximum speed, or
- run the pump at said preset maximum speed, if the calculated speed is higher than the preset maximum speed.

14. The method according to claim 3, wherein said pump condition concerns clogging of the pump.

15. The method according to claim 14, wherein the step of determining if a predetermined condition is fulfilled comprises the steps of:

- running the pump at a desired speed level,
- determining if the power of the motor is higher than a predetermined reference level of the power of the motor, based on the values of the power of the motor obtained by the sensing means for the desired speed level.

16. The method according to any of the claims 14-15, wherein the communicated instructions from the control device to the variable frequency drive means, are

- run the pump at the desired speed level, if it is determined that the predetermined condition is not fulfilled, or
- run the pump reversely at a predetermined speed for a predetermined period of time, and
- run the pump in its normal operation direction at the desired speed level after said predetermined period of time of reverse operation, if it is determined that the predetermined condition is fulfilled.

17. The method according to claim 16, further comprising the steps of:

- repeating said step of determining if the power of the motor is higher than a predetermined reference level of the power of the motor, and
- repeating the steps according to claim 16.

18. The method according to claim 14, wherein the following steps are performed at regular intervals during the operation of the pump:

- running the pump reversely at a predetermined speed for a predetermined period of time, and

- running the pump in its normal operation direction at a desired speed level after said predetermined period of time of reverse operation.

19. Computer program product loadable into a memory of a digital computer device, including software code portions for performing the method of one of the claims 1-18 when said computer program product is ran on said digital computer device.

20. A pump comprising a motor and variable frequency drive means, the latter being arranged to control the operation of the motor by being connected to said motor and to a feeder cable of the pump, the variable frequency drive means comprising a rectifier, an inverter and a DC link extending therebetween, furthermore the pump is operatively connected to a control device, **characterized** in that sensing means is comprised as a part of said variable frequency drive means, which sensing means is operatively connected to said DC link and which is arranged to obtain values of operating parameters of the pump indicating pump conditions, the variable frequency drive means being arranged to communicate to the control device said values of operating parameters, furthermore the control device is arranged to determine if a predetermined condition is fulfilled based on said obtained values of operating parameters and to communicate instructions to the variable frequency drive means, based on the fulfillment of said predetermined condition, in order to control the operation of the motor in accordance with said pump conditions.

21. The pump according to claim 20, wherein said control device is adapted to obtain values of at least one of the following operating parameters: the DC link voltage

level, the DC link current level, the torque of the motor, or the power of the motor.

22. The pump according to claim 21, wherein said control device is adapted to:

- run the pump at a first speed level for a predetermined period of time,
- run the pump at a second speed level for a predetermined period of time, and
- determine if the power of the motor is proportional to the cube of the speed of the motor, based on the values of the at least one operating parameter obtained by the sensing means for the first speed level and the second speed level, respectively.

23. The pump according to claim 22, wherein said control device is adapted to:

- run the pump at a desired speed level, if it is determined that the predetermined condition is fulfilled, or
- stop the operation of the pump a predetermined period of time, if it is determined that the predetermined condition is not fulfilled.

24. The pump according to claim 21, wherein the control device is adapted to:

- maintain the value of the at least one operating parameter at a substantially constant level.

25. The pump according to claim 24, wherein the control device is adapted to:

- run the pump at a desired speed level,
- determine if the power of the motor is lower than a predetermined reference level of the power of the motor, based on the values of the power of the motor obtained by the sensing means for the desired speed level.

26. The pump according to claim 24 or 25, wherein the control device is adapted to:

- run the pump at the desired speed level, if it is determined that the predetermined condition is not fulfilled, or
- calculate the speed of the motor required to reach a predetermined reference level of the power of the motor, if it is determined that the predetermined condition is fulfilled, and
- run the pump at said calculated speed.

27. The pump according to claim 26, wherein the control device is adapted to:

- compare the calculated speed of the pump with a preset maximum speed of the pump, and
- run the pump at said calculated speed, if the calculated speed is lower than the preset maximum speed, or
- run the pump at said preset maximum speed, if the calculated speed is higher than the preset maximum speed.

28. The pump according to claim 21, wherein the control device is adapted to:

- run the pump at a desired speed level,
- determine if the power of the motor is higher than a predetermined reference level of the power of the motor, based on the values of the power of the motor obtained by the sensing means for the desired speed level.

29. The pump according to claim 28, wherein the control device is adapted to:

- run the pump at the desired speed level, if it is determined that the predetermined condition is not fulfilled, or
- run the pump reversely at a predetermined speed for a predetermined period of time, and

- run the pump in its normal operation direction at the desired speed level after said predetermined period of time of reverse operation, if it is determined that the predetermined condition is fulfilled.

30. The pump according to claim 21, wherein the control device , at regular intervals during the operation of the pump, is adapted to:

- run the pump reversely at a predetermined speed for a predetermined period of time, and
- run the pump in its normal operation direction at a desired speed level after said predetermined period of time of reverse operation.

31. A pump station comprising a pump according to any of the claims 20-30, and further comprises an operator unit comprising input means and display means, which is adapted to present information related to the operation of the pump.