The present invention relates to an electrical power distribution method for distributing power between two or more operating units of a wireline tool string downhole performing at least one operation. The electrical power distribution method comprises the steps of recording information indicative of at least one operating condition using one or more sensors comprised in the tool string, comparing the recorded information to a set of predefined intervals of the at least one operating condition, defining a power distribution between the two or more operating units based on the comparison of the recorded information and a predefined interval of the at least one operating condition, classifying the set of predetermined intervals in order to ensure a safe operation, such as classifying whether different operating units are classified as no risk, moderate risk or high risk, and controlling the electrical power distribution of the operating units based on the definition of the power distribution and the classification of the set of predetermined intervals. Furthermore, the present invention relates to a wireline system for carrying out the method according to the invention.
Record information

Operating condition

Compare the recorded information

Predefined intervals

Define a power distribution scheme

Control the electrical power

Fig. 1
Operating Condition Record information

20s - Y - - - - - - - - - - - - - - - 25 Compare the recorded information
Predefined intervals

30 Define a power distribution scheme

40 Control the electrical power

Fig. 2
Operating Condition Record information

- Record information
  - Operating condition

- Compare the recorded information

- Define a power distribution scheme

- Classify the predefined intervals

- Control the electrical power

Fig. 4
10 Record information
20 Compare the recorded information
30 Define a power distribution scheme
40 Control the electrical power

15 Operating condition
25 Predefined intervals
27 Classify the Predefined intervals
35 Compare classification parameters
37 Prioritize the operating conditions

Fig. 5
ELECTRICAL POWER DISTRIBUTION METHOD FOR A WIRELINE TOOL STRING DOWNHOLE

FIELD OF THE INVENTION

[0001] The present invention relates to an electrical power distribution method between two or more operating units of a wireline tool string downhole performing at least one operation. Furthermore, the present invention relates to a wireline system for carrying out the method according to the invention.

BACKGROUND ART

[0002] Downhole wireline tool strings are becoming increasingly complex, as they typically consist of several specialised operational tools to perform more complex operations downhole, e.g. operations involving different types of operations such as drilling, closing valves, setting patches, or logging formation or casing characteristics etc.

[0003] As the complexity and number of tools increase, the amount of electrical power required in the wireline tool string also increases. In order to provide significant power downhole, typically the voltage applied to the wireline is increased to overcome the huge voltage drop over the length of a wireline. However, increasing the voltage may lead to dangerous situations such as electrical breakdown, electrical discharge, and is therefore limited. Also, the possible power transmitted through the wireline is limited due to ordinary heat dissipation in a long wire. Therefore, power transmitted through a wireline to provide power to downhole operating tools is inherently limited.

[0004] One currently used way of accommodating the increased need for electrical power is to increase the number of conductive wires in the wireline and thus increase the total thickness of the conducting part of the wireline delivering the electrical power. Also, many attempts have been made to make the tools use less electrical power while maintaining their ability to perform the same tasks.

[0005] Using a thicker wireline or a wireline containing more conductors increases the weight and cost of the wireline. Furthermore, it increases the power required to transport the wireline, e.g. by use of a tractor, in horizontal parts of a well. This again increases the electrical power required for the tool string, thereby using some or more of the additional power facilitated by the thicker wireline. Minimising energy consumption by the electrical components downhole may be a long and expensive process, since the components used downhole already represent state-of-the-art in respect of minimisation of power consumption due to the inherent shortage of power for power tools and components downhole.

SUMMARY OF THE INVENTION

[0006] It is an object of the present invention to wholly or partly overcome the above disadvantages and drawbacks of the prior art. More specifically, it is an object to provide an improved system able to perform several operations downhole by a normal cable and an improved method for controlling system downhole.

[0007] The above objects, together with numerous other objects, advantages, and features, which will become evident from the below description, are accomplished by a solution in accordance with the present invention by an electrical power distribution method for distributing power between two or more operating units of a wireline tool string downhole performing at least one operation, the method comprising the steps of:

[0008] recording information indicative of at least one operating condition, using one or more sensors comprised in the tool string,

[0009] comparing the recorded information to a set of predefined intervals of the at least one operating condition,

[0010] defining a power distribution between the two or more operating units based on the comparison of the recorded information and a predefined interval of the at least one operating condition,

[0011] controlling the electrical power distribution of the operating units.

[0012] By having a method for distributing the electrical power between two or more operating units in the wireline tool based on an operating condition, it is possible to utilise the limited available electrical power to and in the wireline tool string. By comparing the operating condition to a predefined interval, the recorded operating condition may be detected to determine if the operating condition lies in a dangerous interval for an operating unit and thus affects the electrical power to the operating unit.

[0013] The electrical power distribution method as described above may further comprise a step of classifying the set of predefined intervals.

[0014] By classifying the predefined intervals of the at least one operating condition according to classification parameters with the same level of importance independent of the predefined intervals, the classification parameter may be linked to the operating condition, and the distribution of the electrical power according to the most important classification parameter of the operating condition is thus distributed in a smarter way than by just comparing the operating condition to a single interval.

[0015] Moreover, the step of comparing the recorded information may comprise comparing the recorded information to at least one additional predefined interval.

[0016] Also, the electrical power distribution method as described above may further comprise the step of prioritising the operating conditions of two or more operating units and basing the step of defining the appropriate electrical power distribution on the prioritisation of the operating conditions.

[0017] Furthermore, by comparing the classification parameters, a better decision on what operating condition to consider and how to distribute the electrical power to the operating unit comprising the operating condition may be made.

[0018] By using the information concerning which operating unit is performing an operation, the information may be useful in deciding how to distribute the electrical power if two or more classification parameters from two or more operating units are equal.

[0019] Additionally, the operating unit may comprise a plurality of operating conditions.

[0020] Further, using the information of a predefined order of the operating units in the system may be useful in terms of how to distribute the electrical power if two or more classification parameters are equal and two or more operating units are performing an operation.

[0021] Also, using the information of a predefined order of the rank of the operating units in the system and having the operating conditions in an operating unit to also be ordered
according to a predefined rank may be useful in terms of how to
distribute the electrical power when using a plurality of
operating units and a plurality of operation conditions
comprised in the operating unit, if two or more classification
parameters are equal and two or more operating units are
performing an operation.

By having an operating unit comprising at least one
operating condition and by recording, evaluating, deciding
and controlling according to the method, a master-slave rela-
tionship between the two or more operating may be config-
ured.

The steps of comparing the recorded information,
defining the appropriate electrical power distribution and
controlling the electrical power distribution of the wireline
tool string may be performed uphole at a surface.

The evaluation, decision and control may be
performed at the surface by a computer or by human interaction.

Moreover, the steps of comparing the recorded
information, defining the appropriate electrical power distri-
bution, controlling the electrical power distribution, evaluat-
ing, deciding and/or controlling the wireline tool string may
be performed downhole in the wireline tool string.

The evaluation, decision and control may be
performed downhole by a computer or logic.

In the electrical power distribution method
described above, the operating condition may be a tempera-
ture, a pressure, a power, a vibration, a sound, a voltage, a
current, a light, an angle, a velocity or a frequency or another
operating condition during downhole operations.

Also, the sensor may be a temperature sensor, a
pressure sensor, a wattmeter, an accelerometer, a micro-
phone, a voltmeter, an ammeter, a light sensor, an angle
measuring tool, a transducer, a laser or other sensors for
measuring operating conditions downhole.

Further, the operating unit may be a downhole trac-
tor, a milling tool, a cleaning tool, a stroker tool, a key tool, a
capacitance tool, a laser tool, a laser, a computer, a sensor,
processing unit, an electrical circuit or other operating units
for downhole use.

The present invention also relates to a wireline sys-
tem for carrying out the method as described above, wherein
the wireline system comprises a power distribution unit, two
or more operational tools and two or more sensors for mea-
suring operating conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention and its many advantages will be
described in more detail below with reference to the accom-
panying schematic drawings, which for the purpose of illus-
tration show some non-limiting embodiments and in which

FIG. 1 shows a schematic diagram of a method for
distributing electrical power in a wireline tool,

FIG. 2 shows a schematic diagram of another
method for distributing electrical power in a wireline tool
string,

FIG. 3 shows an example of a temperature range
divided into predefined intervals,

FIG. 4 shows a schematic diagram of yet another
method for distributing electrical power in a wireline tool
string,

FIG. 5 shows a schematic diagram of another
method for distributing electrical power in a wireline tool, and

FIG. 6 shows a cross-sectional view of a well com-
prised a wireline tool string.

All the figures are highly schematic and not neces-
sarily to scale, and they show only those parts which are
necessary in order to elucidate the invention, other parts being
omitted or merely suggested.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a schematic diagram of an electrical
power distribution method for distributing power between
two or more operating units of a wireline tool string perform-
ing at least one operation downhole. The operating units may
be used to perform operations such as milling, cleaning, mea-
suring, stroking, etc. Power is highly limited downhole due to
the loss of power in the long wireline when the wireline tool
string operates several thousands of metres downhole, and the
electrical power distribution method intelligently distributes
the power available to ensure that operations demanding high
amounts of electrical power can be performed. By basing
power distribution between operating units on information
recorded by means of various sensor inputs, the power avail-
able for a given tool string downhole may therefore always be
distributed optimally. Also, depending on the type of opera-
tion, different distribution schemes may be set by the present
method.

A first step 10 of the method concerns recording
information of at least one operating condition 15 of at least
one operating unit. The operating condition 15 is recorded by
using one or more sensors comprised in the wireline tool
string in order to control the electrical power distribution. The
operating condition 15 may be e.g. a temperature in the bore-
hole, a pressure in the borehole, a power usage of an electrical
motor, a vibration during drilling, a sound during drilling, a
magnitude of a supply voltage, a current, a light, an angle, a
frequency or a velocity. The sensor may be e.g. a temperature
sensor, a pressure sensor, a wattmeter, an accelerometer, a
microphone, a gyroscope, a voltmeter, an ammeter, a light
sensor, an angle measuring tool, a transducer, a laser or anoth-
er appropriate sensor. The operating unit may be a driv-
ing unit, such as a downhole tractor, a milling tool, a dril-
ling tool, a cleaning tool, a stroker tool, a key tool, a capaci-
tance tool, a laser tool, a laser, a computer, a sensor, a pro-
cessing unit, an electrical circuit or another operating tool for
downhole use.

Thus, the step of recording information may be to
measure a temperature in a milling tool. The step of recording
information 10 of the operating condition 15 may be per-
formed by the sensor itself or by sending the information to a
computing unit. By separating the sensor and the computing
unit, the sensor can for example be made more resistant to
vibrations as compared to sensors comprising means for
recording the information.

A second step 20 of the method, as shown in FIG. 1,
concerns comparing the recorded information to a set of
predefined intervals 25, e.g. comparing a temperature of a
milling tool during operating condition 15 to a predefined
temperature interval 25 for optimal operation temperature.

When the recorded information has been compared
in step 20 to the set of predefined intervals 25, a next step 30
is to define an appropriate electrical power distribution
between the two or more operating units. The comparison
step 20 of comparing the recorded information and the pre-
defined intervals 25 is used as basis for deciding on an ap-
propriate distribution of the electrical power between operating
tools in step 30. For example, if information is recorded
which is indicative of a temperature in a drill head, and if the
recorded information is found to be within a predefined interval 25 which is e.g. considered to be dangerous for the drilling operation, the electrical power distribution may be re-distributed by changing the distribution of electrical power between the drill bit and a cooling unit, i.e. by decreasing the amount of electrical power for the drill bit and increasing the amount of electrical power for the cooling unit in order to increase the cooling of the drill bit. Due to the limited power available, the cooling unit may only be used when necessary, since the main purpose of the drilling operation is to drill and not to cool the drill bit if not needed.

[0044] The last step 40 of the method shown in FIG. 1 is a step of controlling the electrical power distribution 40 between the two or more operating units based on the step of defining an appropriate electrical power distribution 30, such as decreasing the amount of power to the drill bit and increasing the amount of power to the cooling unit. The step of controlling 40 may be performed by using a computer, a circuit or other electronics capable of distributing the amount of power to the two or more operating units based on the step of defining an appropriate electrical power distribution 30. The step of controlling the electrical power distribution 40 may, in its simplest form, be to control two operating units, e.g. where one of the two operating units gets more electrical power and the other consequently gets less electrical power, the purpose being to ensure that all the electrical power available downhill is used for performing the operation. In a more advanced form of the step of controlling the electrical power distribution 40, a plurality of operating units may be controlled by distributing the electrical power by powering down one or more operating units and distributing the remaining available electrical power to one operating unit, or vice versa.

[0045] An example of a wireline tool string 80 in a casing 78 is shown in FIG. 6 in which the tool string comprises a downhole tractor 66 having an electronic section 72, a drill bit 60 comprising a temperature sensor 62, and a cooling unit 63. The wireline tool string 80 may have been programmed to establish a flow path through an isolation valve in the casing that failed to open by drilling a hole in the isolation valve with the drill bit 60. The temperature sensor 62 records information of a temperature in the drill bit 60 during the operation and sends the recorded information to the electronic section for comparison with a predefined interval.

[0046] A predefined interval may represent a temperature interval, e.g. T>150°C. When the milling tool drills a hole in the valve, the downhole tractor 66 provides a force by which the drill bit 60 presses against the valve to drill and penetrate the valve. If the temperature in the drill bit 60 reaches 160°C during the operation because the pressure generated by the downhole tractor 66 is too high when the drill bit 60 is pressed against the valve, the information in the step of comparing the recorded information is found to be within the predefined interval of T>150°C.

[0047] The electronic section 72 comprising the processing means defines, based on the comparison and a programmed knowledge, e.g. the predefined interval T>150°C considered dangerous for the drill bit 60, how to appropriately distribute the electrical power, e.g. by lowering the electrical power to the downhole tractor 66, thus reducing the force by which the drill bit 60 is pressed against the valve. The definition of the appropriate power distribution may also be based on another appropriate power distribution to avoid overheating, e.g. to increase electrical power to a cooling unit, allowing the cooling unit to increase the cooling effect on the drill. Finally, the computing means controls the distribution of electrical power between the operating units, such as the downhole tractor 66 and the cooling unit 63, by distributing less electrical power to the downhole tractor 66 and thus more to the cooling unit 63 and utilise the new available amount of electrical power to perform the operation.

[0048] By using the method comprising the steps described above for distributing electrical power between two or more operating units in a wireline tool string 80 performing at least one operation, it may be detected if one or more operations is/are performed on inappropriate or even dangerous operating conditions for the two or more operating units and therefore distribute(s) the power appropriately to avoid problems. The steps of comparing the recorded information, defining an appropriate electrical power distribution and controlling the electrical power distribution of the wireline tool string 80 may be performed uphill by a computer, aimed by human interaction, an electronic circuit or similar electrical devices capable of performing the steps mentioned above in part or as a whole. To minimise data transfer over the wireline, the steps may, however, preferably be performed downhill in the wireline tool string 80 by the electronic section 72 comprising the computing means 61 capable of performing the steps mentioned above.

[0049] As shown in FIG. 2, the step of comparing 20 may further comprise a subroutine with a step of classifying the predefined intervals 27 with a set of classification parameters, e.g. according to a level of importance, level of risk, etc. of the operating condition 15. The classification parameter may be a grade, a number or similar indication of whether the operating condition 15 is within an appropriate or inappropriate interval and/or to which degree of risk, such as whether it is classified as no risk, moderate risk or high risk. The classification of the predefined intervals 27 allows the different operating conditions to be categorised based on their criticality to the operation or the tool breakdown. When defining a power distribution, in step 30, between different operating units in a downhole tool, it is very important to secure critical processes requiring electricity. An example may be a drilling operation with a drilling tool having a maximum critical temperature. The temperature may be classified as a high risk predefined interval if the entire tool may break down as a consequence of exceeding the predefined interval. The drilling speed may be another operating condition classified as a low risk predefined interval. The predefined interval of the speed may be given maximum priority during drilling operations seeking to go fast as opposed to e.g. during precise operations or commencement of laterals. However, even when the speed is prioritised based on the purpose of the operation, it is important that the speed is classified as less important than critical operating conditions like temperature. The step of classification of the predefined intervals 27 is not to be mixed with prioritising the operating conditions, since the classification of parameters is used to ensure safe operation of the downhole tool, while the prioritising of operating conditions allows the user to set up an operation where the operating conditions important to this specific type of operation are prioritised over less important operating conditions.

[0050] FIG. 3 shows an example of three predefined intervals 25; a first 50, a second 51 and a third 52 predefined interval 25 that may be classified by three classification parameters A, B and C. As seen in the example of predefined intervals 25 shown in FIG. 3, the set of predefined intervals 25 may be temperature intervals, which further may be classified
by parameters A, B and C, where A < 150° C., 150° C. ≤ B ≤ 175° C. and C > 175° C., wherein the classification parameter A may be defined as no risk of damaging the operating unit, B may be defined as moderate risk of damaging the operating unit, and C may be defined as high risk of damaging the operating unit during operation.

[0051] Using classification parameters A, B, C, the method of distributing the electrical power to two or more operating units facilitates distribution of the electrical power in a more intelligent way than when only comparing the information of the operating condition to the predefined intervals 25.

[0052] The schematic diagram in FIG. 4 shows a method in which the step of defining an appropriate electrical power distribution 30 further comprises a step of comparing classification parameters 35 of at least two different operating conditions 15, e.g., temperature, rotational speed, current draw, etc. As an example, a milling tool performs an operation of drilling a hole in a valve blocking a flow path inside the well according to the described method. A temperature sensor records information of the operating condition 15 indicative of a temperature of the drill in the milling tool, and the sensor for measuring the rotation of the drill records information of the operating condition 15 indicative of revolutions per minute (RPM) of the drill during the step of recording of information 10. The operating conditions 15 indicative of the temperature and the RPM of the drill bit are each compared to a set of predefined intervals 25 classified by a set of classification parameters. The classification of the predetermined interval is chosen, e.g., to define that one operating condition is considered, e.g., the temperature of the drill bit, always has to be within an acceptable tolerance interval of 100-150° C., depending on the material used, since the drill bit may simply break down during too high temperatures, whereas a second operating condition, such as the RPM of the drill bit, would have an acceptable tolerance interval of 10000-15000 RPM due to e.g. optimal drilling performance. Comparing the classification parameters of the predefined intervals 25 between the two operating conditions 15 therefore allows an appropriate power distribution 30 to be defined, and it is thereby possible to control the operating units accordingly.

[0053] By having several operating units each performing the steps of recording information 10, the step of comparing the recorded information 20 and the step of defining an appropriate electrical power distribution 30 for operating conditions 15 of the specific operating units, a master-slave configuration between the two or more operating units may be configured such that a master unit comprises the comparison of classification parameters based on inputs of classification parameters and corresponding appropriate power distributions from each of the operating units, and furthermore, the master unit controls the power distribution.

[0054] Basing the power distribution on a comparison of classification parameters may, in some instances, be difficult if e.g., all operating conditions 15 suddenly lie within a high risk interval. However, as shown in FIG. 5, the definition of an appropriate electrical power distribution 30 may further be based on the preference of the classification parameter of the operating unit performing the at least one operation by a prioritising step 37 prioritising the classification parameters. If, during the comparison of classification parameters 35, two or more classification parameters with equal values from two or more operating units are identified, an optimal power distribution between the units may be achieved by prioritising the operating conditions 37. Furthermore, specific operations may need specific priorities such that during e.g., movement of the tool string 80, the prioritisation is different than the prioritisation during drilling. With respect to the above example, the comparison 35 compares the classification parameter of the temperature of the drill bit. The comparison 35 may then identify that the classification parameters are equal, and additional information may be needed to make a decision. If the operating classification parameters are prioritised, e.g., if the temperature is prioritised over the RPM of the drill bit, the drill bit may be given as much power as possible to perform the drilling operation without compromising the tool by overheating, i.e., if the temperature has higher priority, the drill bit may be given as much power as possible as long as the temperature stays below a certain predefined interval 25. On the other hand, if the temperature increases to above a critical temperature, power to the drill bit may not be increased even though the drill bit may operate at RPM's which are not optimal for the drilling process. Alternatively, during a temperature increase, the electrical power to the drill bit may be kept constant, and the electrical power to a drill cooling unit may be increased, etc. By prioritising the classification parameters, the prioritisation may be used to define an appropriate electrical power distribution if two or more classification parameters are equal. The prioritisation of the operating units may be selected based on e.g., temperature tolerances, power tolerances, pressure tolerances, vibration tolerances, cost/benefit, time consumption, etc. of the operating units and/or other parameters.

[0055] Prioritising the plurality of operating conditions 15 and/or prioritising the plurality of the operating units allows appropriate power distributions during complex operations involving many operational tools and many operating conditions 15.

[0056] FIG. 6 shows a wireline tool string 80 comprising a drive unit, such as a downhole tractor 66, a hydraulic section 68, an electric motor 70, a power distribution unit 73 and a wireline 74.

[0057] By a casing is meant any kind of pipe, tubing, tubular, liner, string etc. used downhole in relation to oil or natural gas production.

[0058] The downhole tractor may have projectable arms having wheels, wherein the wheels contact the inner surface of the casing for propelling the tractor and the tool forward in the casing. A downhole tractor is any kind of driving tool capable of pushing or pulling tools in a well downhole, such as a Well Tractor®.

[0059] Although the invention has been described in the above in connection with preferred embodiments of the invention, it will be evident for a person skilled in the art that several modifications are conceivable without departing from the invention as defined by the following claims.

1. An electrical power distribution method for distributing power between two or more operating units of a wireline tool string downhole performing at least one operation, the method comprising the steps of:
   - recording information indicative of at least one operating condition, using one or more sensors comprised in the tool string,
   - comparing the recorded information to a set of predefined intervals of the at least one operating condition,
   - defining a power distribution between the two or more operating units based on the comparison of the recorded information and the predefined interval of the at least one operating condition,
classifying the set of predefined intervals, in order to
ensure a safe operation, such as classifying whether
different predefined intervals are classified as no risk,
moderate risk or high risk, and
controlling the electrical power distribution of the operat-
ing units based on the definition of the power distribu-
tion and the classification of the set of predefined inter-
vals.

2. An electrical power distribution method according to
claim 1, wherein the step of comparing the recorded infor-
mation comprises comparing the recorded information to at least
one additional predefined interval.

3. An electrical power distribution method according to
claim 1, further comprising the step of:

prioritising the operating conditions of the two or more
operating units and basing the step of defining the appro-
priate electrical power distribution on the prioritisation
of the operating conditions.

4. An electrical power distribution method according to
claim 1, wherein the steps of comparing of the recorded
information, defining the appropriate electrical power distri-
bution, and controlling the electrical power distribution of the
wireline tool string are performed uphole at a surface.

5. An electrical power distribution method according to
claim 1, wherein the steps of comparing the recorded infor-
mation, defining the appropriate electrical power distribution,
and controlling the electrical power distribution are per-
formed downhole in the wireline tool string.

6. An electrical power distribution method according to
claim 1, wherein the operating condition is a temperature, a
pressure, a power, a vibration, a sound, a voltage, a current, a
light, an angle, a velocity and/or a frequency.

7. An electrical power distribution method according to
claim 1, wherein the sensor is a temperature sensor, a pressure
sensor, a wattmeter, an accelerometer, a microphone, a volt-
meter, an ammeter, a light sensor, an angle measuring tool, a
transducer, a laser and/or other sensors for measuring oper-
ating conditions downhole.

8. An electrical power distribution method according to
claim 1, wherein the operating unit is a downhole tractor, a
milling tool, a cleaning tool, a stroker tool, a key tool, a
capacitance tool, a laser tool, a laser, a computer, a sensor,
processing unit, an electrical circuit and/or other operating
units for downhole use.

9. A wireline system for carrying out the method according
to claim 1, wherein the wireline system comprises a power
distribution unit, two or more operational units and two or
more sensors for measuring operating conditions.

10. A wireline system according to claim 9, wherein the
operating unit is a downhole tractor, a milling tool, a cleaning
tool, a stroker tool, a key tool, a capacitance tool, a laser tool,
a laser, a computer, a sensor, processing unit and/or an elec-
trical circuit.

11. A wireline system according to claim 9, wherein the
sensor is a temperature sensor, a pressure sensor, a wattmeter,
an accelerometer, a microphone, a voltmeter, an ammeter, a
light sensor, an angle measuring tool, a transducer and/or a
laser.