Control and Supply System

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The invention relates to a control and supply system for electrical devices, comprising at least one voltage supply and control device above sea level, a subsea cable connecting said voltage supply and control device with the electrical devices, and a control and actuating device which is associated essentially in situ with the electrical devices.

Such control and supply systems are used, for example, in the production of natural gas and mineral oil. In this respect, the application may take place with terrestrial and maritime drilling wells.

With maritime wells one part of the control and supply system is arranged on a platform above the sea surface. This part is in particular a voltage supply and control device which is connected via a subsea cable to the control and actuating device below the sea surface or also on the sea bed. The control and actuating device is connected to various electrical devices, such as motors, electrical actuators and similar equipment via appropriate connecting lines.

With this type of control and supply system known from practice, alternating voltage is transmitted through a subsea cable, whereby the amplitude and frequency of the alternating voltage is already selected such that, for example, on the end of the cable associated with the electrical devices a suitable supply voltage for the devices is provided. For the direct control of each device a separate subsea cable can be provided for each device. The data transmission also occurs via separate subsea cables.

A disadvantage with this known control and supply system is that, for example, for a supply of an electrical device with 240 VAC and with an original voltage feed of 600 VAC for the transmission of the appropriate power to the electrical devices and, for example, a length of subsea cable of 30 or 50 km, a cross-

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sectional area of 100 to 200 mm² is needed for the cable. In addition, data lines are required, so that a subsea cable with a substantial diameter arises.

In the above it has been assumed that 240 VAC is sufficient for the electrical devices. However, it has now been found that higher voltages are required, for example, in order to be able to actuate servomotors as electrical devices with higher power, for example, to close valves in the production of natural gas or mineral oil in a maximum time period of one minute. With the application of such electrical devices supplied with a higher voltage the cross-sectional area of the subsea cable with the known control and supply system would increase still further.

In addition, it has been found in practice that on starting a servomotor as an electrical device and in particular for servomotors with a higher power, even with a slow starting process, a return signal occurs via the subsea cable to the voltage supply and control device indicating the starting process of the servomotor as a short circuit at the end of the cable. This leads to the switching off of a system automatically protected against short circuit.

Furthermore, with the previously described control and supply system an efficiency for the overall system of only 27% is obtained referred to the output power.

With another control and supply system known from practice, transmission of alternating voltage also occurs through the subsea cable. However, with this system an alternating voltage, for example, at 10,000 VAC is transmitted via the subsea cable and at the control and actuating device it is reduced, for example, by a transformer to the voltage values required by the electrical devices. In addition, a number of power capacitors must be used to smooth the voltage again after the reduction. In order to be able to reduce, where required, the conductor cross-sectional areas for the subsea cable with this other known system, a power factor correction is also implemented to obtain an adequate

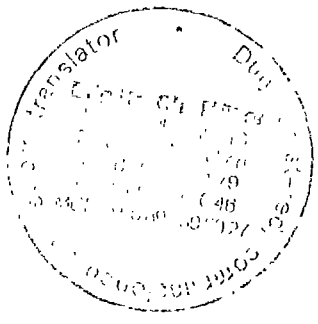
efficiency for the overall system. Further devices, which are very complex and expensive, are needed for this correction.

However, even with the complete expansion of the previously mentioned system, the efficiency normally is less than 70% and the cross-sectional areas for a conductor in the subsea cable amount to about 16 or 26 mm^2 for a length of 30, or respectively 50 km.

The object of the invention is to improve a control and supply system of the type mentioned at the beginning such that with less complexity, higher efficiency and better system usage, supply is possible over larger distances.

This object is solved in relationship with the characteristics of the generic term of Claim 1 such that the voltage supply and control device for the production of a direct voltage for feeding into the subsea cable comprises at least one AC/DC converter, the control and actuating device is associated with at least one DC/DC or DC/AC converter for converting the direct voltage transmitted by the subsea cable into a direct voltage or alternating voltage and the voltage generated thereby can be transmitted to the electrical devices via the connecting lines.

This means that according to the invention direct voltage is transmitted via the long subsea cables, whereby the conversion from alternating voltage into direct voltage or vice versa from direct voltage into alternating voltage only takes place at the ends of the subsea cable. With direct voltage and the corresponding direct current, only real power is transmitted via the subsea cable and no apparent power. This means that the power factor is 1. Due to the direct voltage transmission along the subsea cable, even with high voltages only slight losses are present in comparison to a transmission of alternating voltage with previously known systems.



Furthermore, with the transmission of direct voltage only small cross-sectional areas arise for a conductor in the subsea cable which may be only one tenth or less of the cross-sectional areas for the transmission of alternating voltage.

Due to the DC/DC or DC/AC converter in the area of the control and actuating device, a corresponding conversion of the direct voltage takes place into the required direct or alternating voltage values, such as for example, 240 V or 300 V with the appropriate frequency, for the electrical devices such as motors, actuators and similar equipment.

The system according to the invention is therefore distinguished by its simplicity and higher efficiency (at least 70%), whereby a significant cost saving can be obtained solely by the significant reduction of the cross-sectional area of the conductors in the subsea cable.

A simple voltage source for the system, which can also normally be used for other applications, can be seen in that an alternating voltage source is connected to the supply voltage and control device for the supply with an especially three-phase alternating voltage source.

With the previously known systems it is also possible to transmit data between the voltage supply and control device and the control and actuating device. Normally, a separate cable is used for this.

According to the invention, another advantage arises in that the direct voltage transmission along the subsea cable is free of any high frequencies and therefore voltage frequencies directly corresponding to the direct voltage can be modulated onto the direct voltage in a simple manner for data transmission. This can especially take place in that the voltage and control device and the control and actuation device each exhibit at least one data modulation device.

An especially simple and effective type of data feed can be seen in that the data modulation device of the voltage supply and control device is arranged after the DC/DC or AC/DC converter.

A suitable input of information or data can occur directly in the area of the data modulation device via appropriate input devices. However, there is also the possibility that a suitable data and signal feed occurs from a more remote position. To achieve this, the voltage and control device can be connected to an external data transmission device. The appropriate data can be transmitted through it to the data modulation device or received from it.

In order to be able to receive or feed in data in a simple and analogous manner also in the area of the control and actuation device, the data modulation device of the control and actuation device can be positioned before the DC/DC or DC/AC converter.

In this way the data is fed in and also obtained from the direct voltage.

In order to prevent the occurrence of high currents and, where applicable, of damage to the relevant electrical devices, especially on the sea bed, an overcurrent control device can be assigned to the DC/DC or DC/AC converter.

With a DC/DC converter on the sea bed the high direct voltage of a number of thousands of volts fed from the surface of the sea is split up into appropriate direct voltages for the supply of the individual devices on the sea bed.

In order to be certain that the electrical devices are supplied with suitable voltage values, the DC/AC converter can be inductively coupled with an alternating voltage measurement device, especially with a voltage shunt regulator. Due to the voltage shunt regulator, the system can, for example, run under full voltage also before the actuation of the electrical devices, whereby

the voltage shunt regulator takes over the dynamic load regulation and then can reduce the voltage to appropriately low values.

Due to the inductive coupling, it is established as a further characteristic of the invention that suitable plug connections or other connections between subsea cables and electrical devices are not operated with direct voltage. It is generally known that even slight moisture is hazardous for the transmission of direct voltage and especially salt water acts as a galvanic element with direct voltage and would very quickly damage metallic contact surfaces. In order to keep the expense of such connections low, the inductive coupling takes place below sea level and the following passage of the voltage occurs through alternating voltage for which the usual, known maritime electrical connectors can be used.

By using the usual electrical connectors, it is also possible for all the connected parts to be recovered and to be fetched from below sea level and, for example, to service them and reuse them later. According to the invention a fixed and non-releasable connection between, for example, the subsea cable and appropriate devices is not required.

For the inductive coupling a transformer can be used, which, for example, also directly carries out the conversion of the direct voltage into the alternating voltage values for the electrical devices.

Such a transformer may comprise two separable, largely symmetrical and mutually associated coil half-cores.

In order to be able to simultaneously interchange data over the air gap between the coil half-cores, a data modulation device can be assigned to each coil half-core for the transmission of data.

In order to control and monitor the conversion of the direct voltage into alternating voltage and to control and monitor at least the appropriate data

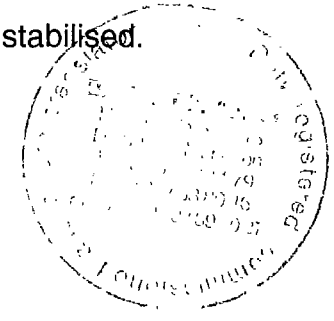
modulation devices of the coil half-cores, a coupling control device appropriate to controlling the data modulation devices, the DC/AC converter and/or the alternating voltage measurement device can be assigned to each coil half-core. A return signal to the voltage supply and control device for regulating the direct voltage can be provided from the alternating voltage measurement device, whereby the return signal occurs via the appropriate coupling control devices, data modulation devices for the coil half-cores, data modulation device of the control and actuating device, subsea cable and data modulation device of the voltage supply and control device. In this way a continuous bidirectional data interchange between the voltage supply and control device and the control and actuation device is possible.

With a simple embodiment without further control devices, the alternating voltage measurement device can be connected to the electrical devices for their supply.

In order to measure the alternating voltage provided by the DC/AC converter in a simple manner by the alternating voltage measurement device and to supply the electrical devices with suitable voltage values, the alternating voltage measurement device can in particular measure an amplitude of the alternating voltage.

In this connection, it is advantageous if the alternating voltage supplied by the DC/AC converter is, for example, a rectangular wave voltage. With this voltage the various electrical devices can be supplied with a stable voltage and sufficient power.

A separate voltage stabilisation, for example, using a Zener diode arrangement is no longer necessary due to the alternating voltage measurement device with voltage shunt regulator according to the invention, because the alternating voltage provided by this circuit is already statically and dynamically stabilised.



For the transmission of the direct voltage and also the electrical signals along the subsea cable, the cable can be advantageously formed from coaxial conductors. These exhibit optimum properties with regard to attenuation and immunity with regard to radiated noise and they enable a high data transmission rate of at least 100 to 600 kBaud. Furthermore, bidirectional transmission of data along the subsea cable can also be carried out simply.

The transformer can be realised such that the air gap between the two coil half-cores is, for example, at the most 4 mm or especially at the most 2 mm. In addition, appropriate materials for the coil half-cores can be used which are not susceptible to attack by sea water, such as arrangements of corrosion-resistant transformer steel sheet or plastic encapsulated magnetic powder mixtures for the appropriate coil core materials.

In order to be able to also pass data in the direction of the voltage supply and control device directly from the electrical devices or the alternating voltage measurement device, the voltage shunt regulator can be realised bidirectionally.

Due to the application according to the invention of direct voltage or direct current and the resulting possible small cross-sectional areas of the conductors in the subsea cable, there is also the possibility that for each electrical device a separate connecting conductor can be provided in the subsea cable. In this relationship it must be noted that an electrical unit, for example, a single motor or a single actuator can also be a suitable tree structure or group of electrical motors, actuators or other electrical devices.

A suitably simple coupling of data – also multi-channel – can be realised in that the system exhibits a multiplexer device for data transmission.

In the following an advantageous embodiment of the invention is explained in more detail based on the figures enclosed in the drawing.

The following are shown:

Fig. 1a-c a schematic diagram of various control and supply systems as a comparison, whereby the control and supply system according to the invention is illustrated in Fig. 1c;

Fig. 2 a block diagram of the control and supply system according to the invention as in Fig. 1c.

Fig. 1 shows various control and supply systems of which those in Figs. 1(a) and (b) are known in practice.

With the control and supply system according to Fig. 1(a) a voltage supply and control device 3 with appropriate voltage source and multiplexer device 25 is arranged above the surface of the sea 4. The voltage supply occurs via alternating voltage, which is transmitted directly via a subsea cable 5 to a control and actuating device 6. This is arranged below sea level and is connected via connecting lines 26 to appropriate electrical devices 2 or electrical units 24. Such an electrical unit 24 may be formed by a group of electrical devices 2, which, for example, are arranged in the form of a tree structure and are controlled and actuated on a common basis.

A data cable 27 is provided for the data transmission between the voltage supply and control device 3 and the control and actuating device 6. This is preferably composed of coaxial conductors.

Normally, an alternating voltage of a maximum of 600 VAC is transmitted along the subsea cable 5. For the supply of the appropriate electrical devices with 240 VAC and appropriate power, cross-sectional areas of at least 175 mm^2 for appropriate conductors are required in the subsea cable for, for example, a length of 50 km.

The control and actuation device 6 includes at least one motor actuation device 31 and a control system 32. The various motors as electrical devices 2 can be used here for the actuation of valves, BOPs (blow-out preventers) and similar equipment which is used for the production of mineral oil or gas on the sea bed.

With the other known control and supply system according to Fig. 1(b) transmission of alternating voltage along the subsea cable 5 also occurs. In this case however a voltage of a maximum of 10,000 VAC is transmitted which is reduced before the control and actuation device 6 by a suitable transformer 33 to the voltage values required for the electrical devices. Also, with this known system a separate data conductor 27 is provided as a coaxial cable or similar. The control and actuating device 6 according to Fig. 1(b) requires expensive power capacitors 34 in order to smooth the reduced alternating voltage appropriately. In addition, with this system, as with the system according to Fig. 1(a), power factor correction devices are needed to lower the apparent power of the system. Such correction devices are normally quite expensive and consist of capacitors or similar.

With the system according to Fig. 1(b) and for appropriate voltage values and powers for the electrical devices on the sea bed, conductor cross-sectional areas in the subsea cable of, for example, at least 75 mm^2 arise for a length of 50 km or with power factor correction at least a cross-sectional area of 26 mm^2 for a 50 km length.

According to the invention and as in Fig. 1(c), alternating voltage is not transmitted via the subsea cable 5, but instead direct voltage is used. The voltage supply and control device 3 exhibits at least one AC/DC converter 7, which converts a suitable alternating voltage from an alternating voltage source 9, see Fig. 2, into direct voltage. In the area of the control and actuation device 6 a DC/DC or DC/AC converter 8 is provided analogously for the conversion of the direct voltage into direct or alternating voltage. Since, according to the invention, a direct voltage is transmitted through the subsea cable 5,

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correspondingly no transmission of high frequency voltages occurs, so that signals for data transmission can be modulated onto the direct voltage in a simple manner. This takes place through the multiplexer device 25 and through an appropriate cable coupler 34. Demodulation of the data occurs appropriately in the area of the control and actuation device 6.

With the implementation of the converter 8 as DC/DC converter a conversion of the high direct voltage transmitted through the subsea cable 5 occurs appropriately into the direct voltages required for the supply of the appropriate device on the sea bed. In this connection it must be noted that with a direct voltage supply of the device at the sea surface a suitable data interchange with this device is simplified, because appropriate data signals can be modulated onto the direct voltage signal in a simple manner.

In the following the control and supply system 1 according to Fig. 1(c) is described in more detail based on a block diagram in Fig. 2.

With the embodiment of the control and supply system 1 according to the invention and as in Fig. 2, a voltage supply and control device 3 is arranged above the sea surface 4 and a control and actuation device 6 below this sea surface 4. The link between these two is realised by a subsea cable 5.

The voltage supply and control device 3 comprises at least one AC/DC converter 7 and a data modulation device 10. Furthermore, a surface control device 28, through which the control of the AC/DC converter 7 and also of the data modulation device 10 occurs, is assigned to both previously mentioned units.

The voltage supply and control device 3 is connected to an alternating voltage source 9 which provides a three-phase alternating voltage. Furthermore, the voltage supply and control device 3 is connected to a data transmission device 11 which can be positioned remote from the voltage supply and control device

3, but which is still part of the control and supply system 1. The control of the complete system and its monitoring can occur through the data transmission device 11.

The arrows shown between the various units in the system indicate through the arrow direction a transmission of voltage or data, whereby generally a bidirectional data transmission is possible.

The control and actuation device 6 is positioned below the sea surface 4 and, for example, on the sea bed. It comprises a data modulation device 12 for demodulation of the data transmitted through the subsea cable 5, but also for the modulation of appropriate data onto the voltage transmitted through the subsea cable 5 when such data is transmitted in the reverse direction from the control and actuation device 6 to the voltage supply and control device 3.

Following the data modulation device 12, the control and actuation device 6 comprises a DC/AC converter 8. Using this, the direct voltage transmitted through the subsea cable 5 is converted back into an appropriate alternating voltage. An overcurrent control device 13 is assigned to the DC/AC converter 8. Following conversion of the direct voltage into alternating voltage by the DC/AC converter 8, an inductive transmission of the alternating voltage occurs to an alternating voltage measurement device 14. The inductive transmission occurs through a transformer 16 consisting of two coil half-cores 17, 18. An air gap 23 is formed between these coil half-cores.

The alternating voltage measurement device 14 is especially used for the determination of amplitude values of the alternating voltage and a voltage shunt regulator 15 is assigned to the measurement device. This provides an appropriate static and dynamic stabilisation of the alternating voltage, whereby the voltage shunt regulator 15 is bidirectional and, together with the alternating voltage measurement device 14, is positioned on the output of the transformer 16. Then, the stabilised alternating voltage is passed to a subsea voltage

source 30 to which the various electrical devices 2 or units 24 are connected via electrical connecting lines 26.

A data modulation device 19, 20 as well as a coupling control device 21, 22 is assigned to each coil half-core 17, 18. The transmission of data occurs via the data modulation devices 19, 20 and the coupling control devices 21, 22 are used for the control of the various data modulation devices 12, 19, 20 as well as alternating voltage measurement device 14 with voltage shunt regulator 15. Furthermore, the coupling control devices 21, 22 are used for the interchange of data, for example, with the alternating voltage measurement device 14 with voltage shunt regulator 15 and, for example, with a subsea electronic module 29. This electronic module contains the appropriate electronics for controlling the various items of equipment below sea level and in particular on the sea bed, such as valves, blow-out preventers, actuators and similar equipment. Generally, the appropriate electronics is contained redundantly in the electronic module.

In the following the functioning principle of the control and supply system 1 according to the invention is briefly described based especially on Fig. 2.

According to the invention, supply of the control and actuation device 6 occurs with direct voltage through the subsea cable 5. Here, the direct voltage is converted to alternating voltage by an appropriate DC/AC converter 8 only when it reaches the end of the long subsea cable. Above the surface of the sea a three-phase alternating voltage is converted by an AC/DC converter to, for example, an output voltage from 3000 to 6000 V. The voltage value depends on the power requirements of the system.

Then, the stable and filtered direct voltage is passed to coaxial conductors in the subsea cable, whereby first data signals are modulated onto the voltage via a suitable data modulation device such as a modem or similar device.

Since coaxial conductors exhibit optimum properties with regard to attenuation and electrical noise, high data transmission rates of at least 100 to 600 kBaud are possible using such conductors.

On the sea bed or below the surface of the sea a demodulation of the data signals occurs using a suitable data modulation device, again such as a modem. Then, conversion of the voltage occurs by a DC/AC converter into, for example, a rectangular wave voltage of 300 V with a frequency of 20 kHz. This alternating voltage can be transmitted over normal connection equipment to the various electrical devices. Only slight filtering is required without large electrolytic capacitors. The transformer 16 used for the conversion of the alternating voltage of the DC/AC converter to the appropriate voltage values comprises two coil half-cores 18, 19, which are separated by an air gap. The coil half-cores are assigned to one another, separable from one another and are formed mutually symmetrically. This transformer provides the inductive coupling.

Then follows a measurement of the amplitude of the rectangular wave voltage by the alternating voltage measurement device 14, to which furthermore a voltage shunt regulator 15 is assigned. A static and dynamic stabilisation of the output voltage is largely provided by these two devices in the transformer output. Appropriate losses from the transformer and other devices in the control and actuation device 6 can be dissipated directly through contact to the sea water via appropriate wall construction on the device.

Data transmission from the measurement device 14 via the data modulation device 20 and 19 and via the further data modulation device 12 and back to the voltage supply and control device 3 is possible for regulation of the voltage supply.

Using appropriate calculations for the required voltage values and powers, a conductor cross-sectional area of only approximately 2 mm² arises for, for

example, a length of 50 km of subsea cable with the voltage control and supply system according to the invention. This is a substantially lower cross-sectional area than with systems known in practice, see Figs. 1(a) and (b).

In addition, high data transmission rates are possible due to the simple modulation and demodulation with respect to the direct voltage and the coaxial cable used. Through the devices used in the system according to the invention a stable supply voltage and high system reliability arise.

Claims

1. Control and supply system (1) for electrical devices (2) with at least one voltage supply and control device (3) above sea level (4), a subsea cable (5) connecting said voltage supply and control device with the electrical devices (2), and a control and actuating device (6) which is associated essentially in situ with the electrical devices (2), **characterised in that** the voltage supply and control device (3) for producing a direct voltage for feeding into the subsea cable (5) comprises at least one AC/DC converter (7), the control and actuating device (6) is associated with at least one DC/DC or DC/AC converter (8) for converting the direct voltage transmitted by the subsea cable (5) into a direct voltage or an alternating voltage, and the voltage generated thereby can be transmitted to the electrical devices (2) via the connecting line.

2. Control and supply system according to Claim 1, **characterised in that** an alternating voltage source (9) is connected to the voltage supply and control device (3) for the supply with especially a three-phase alternating voltage.

3. Control and supply system according to Claim 1 or 2, **characterised in that** the voltage supply and control device (3) and the control and actuation device (6) each comprise at least one data modulation device (10, 12, 19, 20).

4. Control and supply system according to one of the previous claims, **characterised in that** the data modulation device (10) of the voltage supply and control device (3) is positioned after the AC/DC converter (7).

5. Control and supply system according to one of the previous claims, **characterised in that** the voltage supply and control device (3) is connected to an external data transmission device (11).

6. Control and supply system according to one of the previous claims, **characterised in that** the data modulation device (12) of the control and actuation device (6) is positioned after the DC/DC or DC/AC converter (8).

7. Control and supply system according to one of the previous claims, **characterised in that** an overcurrent control device (13) is assigned to the DC/DC or DC/AC converter (8).

8. Control and supply system according to one of the previous claims, **characterised in that** the DC/AC converter (8) is inductively coupled with an alternating voltage measurement device (14) especially with a voltage shunt regulator (15).

9. Control and supply system according to one of the previous claims, **characterised in that** a transformer (16) is provided for inductive coupling between at least DC/AC converter (8) and alternating voltage measurement device (14).

10. Control and supply system according to one of the previous claims, **characterised in that** the transformer comprises two separable coil half-cores (17, 18) which are largely symmetrical and assigned to one another.

11. Control and supply system according to one of the previous claims, **characterised in that** a data modulation device (19, 20) for the transmission of data is assigned to each coil half-core (17, 18).

12. Control and supply system according to one of the previous claims, **characterised in that** a coupling control device (21, 22) appropriate for the control of the data modulation devices (19, 20) of the DC/AC converter (8) and of the alternating voltage measurement device (14) is assigned to each coil half-core (17, 18).

13. Control and supply system according to one of the previous claims, **characterised in that** the alternating voltage measurement device (14) is connected to the electrical devices through the connecting line (26).

14. Control and supply system according to one of the previous claims, **characterised in that** especially an amplitude of the alternating voltage can be measured by the alternating voltage measurement device (14).

15. Control and supply system according to one of the previous claims, **characterised in that** the alternating voltage provided by the DC/AC converter (8) is a rectangular wave voltage.

16. Control and supply system according to one of the previous claims, **characterised in that** the alternating voltage provided by the alternating voltage measurement device (14) with the voltage shunt regulator (15) is statically and dynamically stabilised.

17. Control and supply system according to one of the previous claims, **characterised in that** the transmission of data along the subsea cable (5) can be carried out bidirectionally.

18. Control and supply system according to one of the previous claims, **characterised in that** an air gap (23) between the coil half-cores (17, 18) is a maximum of 4 mm and especially a maximum of 2 mm wide.

Brigitte Ch. Müller

19. Control and supply system according to one of the previous claims, **characterised in that** the voltage shunt regulator (15) is formed bidirectionally.

20. Control and supply system according to one of the previous claims, **characterised in that** a separate connecting line is provided in the subsea cable (5) for each unit (24) of electrical devices (2).

21. Control and supply system according to one of the previous claims, **characterised in that** the system (1) comprises a multiplexer device (25) for the data transmission.

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Munich, 04 April 2003

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