

SUBSEA POWER DISTRIBUTION DEVICE AND SYSTEM

TECHNICAL FIELD

The present invention relates to distribution of electric power to subsea equipment.

- More particularly, the invention relates to a subsea power distribution device,
5 comprising a watertight housing accommodating a transformer, the transformer having a primary winding and a plurality of secondary windings; input terminals, electrically connected to the primary winding, arranged to be connected to a remote power supply; and output terminals, electrically connected to the secondary windings, arranged to be connected to subsea power consuming devices.
- 10 The invention also relates to a corresponding subsea power distribution system and method.

BACKGROUND

- In offshore installations there is an increasing use of electrically powered subsea equipment, such as subsea production installations. Such subsea equipment may include,
15 i.a., compressors, pumps, and any other electrically powered subsea equipment.

- The electrical power to be distributed to such subsea equipment may be supplied from land, e.g. an onshore power plant, or from an offshore power generating facility, e.g. on a ship or platform.

- 20 Such subsea equipment may have high power requirements, and electric power must usually be transferred across long distances. In order to provide an efficient power transfer across long distances, a high voltage is used for the remote power supply.

- 25 The high voltage power supply is connected to a subsea power distribution device which includes a transformer that provides a lower voltage power supply which is connected to subsea power consuming devices. The transformer may be accommodated in a watertight housing. The transformer may be a multi-winding transformer, having a primary winding and a plurality of secondary windings. The

primary winding is electrically connected to input terminals which arranged to be connected to the remote, high voltage power supply. The secondary windings are electrically connected to output terminals which are further arranged to be connected to the subsea power consuming devices.

5

A disadvantage of such an arrangement is that the secondary transformer windings have no protection against a failure in one of the circuits connected to a secondary winding, e.g. a ground fault, an overload or a short circuit in one of the subsea power consuming devices.

10

Such a failure may therefore result in the shutdown or disconnection of the entire transformer. This has substantial operational consequences, e.g. loss of operational time and costs, and should be avoided when possible.

SUMMARY

15 Disadvantages and/or shortcomings of background art have been overcome by a device and a system as have been set forth in the appended claims.

In particular, in a first aspect of the present invention, there is provided a subsea AC power distribution device, comprising a watertight housing accommodating at least one transformer, the transformer having a primary winding and a plurality of
20 secondary windings; input terminals, electrically connected to the primary winding and arranged to be connected to a remote AC power supply; output terminals, electrically connected to the secondary windings and arranged to be connected to subsea power consuming devices; switches arranged to break the connections between each secondary winding and a corresponding output terminal, the switches
25 being arranged within the watertight housing. Each switch includes a switch actuator and the watertight housing is configured with a first compartment and a second compartment separate from the first compartment, the transformer being arranged within the first compartment and the switches being arranged in the second compartment.

30 In a second aspect of the present invention, there is provided an AC subsea power distribution system, comprising a remote AC power supply, a subsea AC power

distribution device according to the first aspect, a plurality of subsea power consuming devices, and primary electrical connections which interconnect the remote power supply and the input terminals of the subsea power distribution device, and secondary electrical connections which interconnect the output terminals of the subsea power distribution device and the subsea power consuming devices.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be discussed in closer detail in the following with reference to the drawings, wherein

10 Figure 1 is a schematic block diagram illustrating aspects of a subsea power distribution device.

Figure 2 is a schematic block diagram illustrating certain further aspects of a subsea power distribution device.

15 Figure 3 is a schematic block diagram illustrating certain further aspects of a subsea power distribution device.

DETAILED DESCRIPTION

Figure 1 is a schematic block diagram illustrating aspects of a subsea power distribution device.

The subsea power distribution device comprises a watertight housing 101 which accommodates at least one transformer 102. Also shown are additional transformers 103, 104, which may also be included in the watertight housing 101. As will be appreciated, any suitable number of transformers, for instance 1, 2, 3 or 4
5 transformers, may be included in the power distribution device. Each additional transformer 103, 104 may e.g. be equal to, similar to, or different from the transformer 102.

The transformer 102 has a primary winding and a plurality of secondary windings, i.e., a multiwinding transformer. In figure 1 the primary winding has not been
10 shown, for simplicity of illustration. The plurality of secondary windings, which in this example includes 4 secondary windings, has been illustrated within the transformer 102.

Each secondary winding is feeding one power consuming device. As used herein, the term power consuming device should be understood to mean either one single
15 power consuming unit or a power distribution circuit segment which may include a plurality of power consuming units.

Although not illustrated in figure 1, the subsea power distribution device 100 includes input terminals that are electrically connected to the primary winding. These input terminals are also arranged to be connected to a remote power supply.

20 The remote power supply may have high supply voltage of typically 50-150 kV, for instance 90kV. The high voltage power may be transferred over a long distance, such as from land, e.g. an onshore power plant, or from an offshore power generating facility, e.g. on a ship or platform, to the subsea site.

The power distribution device 100 further includes output terminals which are
25 electrically connected to the secondary windings and arranged to be connected to subsea power consuming devices.

The secondary windings may typically supply a operating voltage in the range of 10 to 40 kV, or more particularly, in the range of 20 to 36 kV, e.g., 24kV.

Further, switches are arranged to break the connections between each secondary winding and a corresponding output terminal. The switches, including the illustrated switches 113 and 123, are arranged within the watertight housing.

5 The arrangement of the switches arranged to break the connections between each secondary winding and a corresponding output terminal avoids complete production stop in the event of an electrical fault in a secondary circuit, e.g., a overload, short-circuit or earth fault in a subsea power consuming device. Each switch makes it possible to isolate each separate secondary circuit in order to disconnect only the circuit which has a fault. When a secondary circuit is to be connected or
10 disconnected, such isolating switches will give the opportunity of performing such a circuit isolation operation without the disconnecting the complete subsea transformer.

The switches used in the power distribution device may e.g. be designed for operating in a voltage range of 10 to 40 kV, or more particularly, in the range of 20
15 to 36 kV, e.g., 24 kV. Advantageously, dielectric insulating fluid (oil) is used to fill the switch gap, which implies that a switch rated for a particular voltage when operated in air, may operate at a substantially higher (such as approx. three times higher) voltage when insulating fluid (oil) is used.

As a simplified, illustrative example, shown in figure 1, one secondary winding
20 111 in the transformer 102 is connected through a conductor 112 to a switch 113. A further connector is connected between the switch 113 and the output terminal 114, which is arranged to be connected to a subsea power consuming device. Likewise, another secondary winding 121 in the transformer 102 is connected through a conductor 122 to a switch 123. A further connector is connected between the
25 switch 123 and the output terminal 124, which is also arranged to be connected to a subsea power consuming device.

Advantageously, each switch, e.g. the switch 123, is placed as close as possible to the secondary winding of the transformer, so as to minimize the risk of a fault between the secondary winding and the switch, since such a fault cannot be isolated
30 by means of the switch.

Preferably, each secondary winding of the transformer, such as the transformer 102, is provided with a corresponding switch, connected to the secondary winding through a conductor.

Each switch includes a switch actuator, which actuates the switching function of the switch. For instance, the switch 113 is actuated by the switch actuator 115. Preferably, as shown, two other, correspondingly operated switches are actuated by the same switch actuator 115.

Likewise, the switch 123 is actuated by another switch actuator 125. Preferably, as shown, two other, correspondingly operated switches are actuated by the same switch actuator 125.

In a particular advantageous aspect, the watertight housing 101 is configured with a first compartment 131 and a second compartment 141. The second compartment 141 is separate from the first compartment 131. Further, in this configuration, the transformer is arranged within the first compartment 131 while the switches are arranged in the second compartment 141.

The first compartment 131 and the second compartment 141 are advantageously oil-filled. Advantageously, the oil used is a dielectric isolating oil of a type known as transformer fluid. An example is known as MIDEL 7131.

The first 131 and second 141 compartments may be configured as separate parts or as portions of a divided enclosure. The compartments, including the divided enclosure, should be designed and arranged to withstand subsea environment conditions, i.e. water pressure, salt, temperature variations, etc. To this end, the compartments may be made of a strong steel casing with cooling fins for heat exchange. The enclosure may advantageously include a top cover and suitable bushing boxes. Appropriate seals, closures, penetrators and connectors to sea-water for subsea environment may be chosen as appropriate by the skilled person.

In one aspect, the switch actuator is (or the switch actuators are) contained within the watertight housing. Hence, as shown, the switch actuators 115 and 125 are contained within the watertight housing 101.

More specifically, in the configuration wherein the watertight housing 101 has a first compartment 131 and a second compartment 141, the switch actuator is advantageously contained within the second compartment 141. In this configuration, electric penetrators are needed between the first and second compartments.

- 5 In an alternative aspect, the switch actuator is arranged external to the watertight housing. In this case, it may be necessary to arrange a mechanical shaft through the shell of the watertight housing. This leads however to certain disadvantages with respect to obtaining a durable and reliable seal between the shaft and the shell of the watertight housing. This problem has been solved by arranging a magnetic coupling
10 between the actuator's electric motor, arranged outside the watertight housing, and a movable mechanism of the switch.

In any of the above aspects, the switch actuator may be connected to and arranged to be controlled by a control unit which is arranged separately from the watertight housing.

- 15 The switch actuator may advantageously be an electrical switch actuator, e.g. including a motor, mechanical drive gear, a power supply such as a battery, and a control unit. The electric switch actuator may be configured to be fail safe. The battery may include an internal battery, an external battery, or a combination.

- Alternatively, the switch actuator may be a hydraulic or electro-hydraulic switch
20 actuator.

Figures 2 and 3 are schematic block diagrams illustrating certain further aspects of a subsea power distribution device.

- The subsea power distribution device 200 comprises a watertight housing in the same way as the device 100 described above with reference to figure 1, although
25 this housing has not been illustrated in figures 2 and 3. The watertight housing accommodates a transformer which has a primary winding, schematically illustrated at 210 and a plurality of secondary windings; namely, the four secondary windings 211, 221, 231 and 241. Input terminals (schematically illustrated as one line) are electrically connected to the primary winding 210 and arranged to be connected to a
30 remote power supply. In figure 2, a switch 250 has been shown to be interconnected in the supply line between the remote power supply and the primary winding 250.

The subsea power distribution device 200 further comprises output terminals, which are electrically connected to the secondary windings and arranged to be connected to subsea power consuming devices, illustrated at 216, 226, 236 and 246. Switches, illustrated in figure 2 at 211, 221, 231 and 241 respectively, are arranged to break
5 the connections between each secondary winding and a corresponding output terminal which leads to a corresponding subsea power consuming device. The switches are arranged within the watertight housing, in a corresponding way as disclosed and illustrated for the power distribution device 100 illustrated in figure 1.

10 Additionally, the subsea power distribution device 200 may include any of the optional features, or any combination of the optional features, which have already been described above for the power distribution device 100 illustrated in figure 1.

Figure 3 illustrates a similar configuration as that shown in figure 2. Each subsea power consuming device may include an additional power switch within the device itself, or more specifically, as suggested in figure 3, in a separate switch unit
15 attached to or included in the same housing as the corresponding subsea power consuming device. The power switches included in the power consuming device may e.g. be a power switch in a Variable Speed Device (VSD).

The subsea power distribution device disclosed above, with any combination of aspects and possible or optional features, may be included in a subsea power
20 distribution system. The subsea power distribution system comprises a remote power supply, with a high voltage of typically 50-150 kV, for instance 90kV. The high voltage power may be transferred over a long distance, such as from land, e.g. an onshore power plant, or from an offshore power generating facility, e.g. on a ship or platform, to the subsea site.

25 The subsea power distribution system further comprises a subsea power distribution device as disclosed above, e.g. as shown and described with reference to figures 1, 2, 3 and 4, and a plurality of subsea power consuming devices, such as compressors, pumps, etc.

The subsea power distribution system also includes primary electrical connections
30 which interconnect the remote power supply and the input terminals of the subsea power distribution device.

The subsea power distribution system also includes secondary electrical connections which interconnect the output terminals of the subsea power distribution device and the subsea power consuming devices.

- 5 It should be appreciated by the skilled person that the disclosed subsea power distribution device and subsea power distribution system may employ three-phase AC or one-phase AC supply voltage/current, circuits and elements.

The disclosed subsea power distribution device and subsea power distribution system may have at least some of the following advantages:

- 10 A ground fault, or another electrical fault, in one secondary circuit may have no impact on the other secondary circuits.

The possibility of isolating one faulty circuit so this fault does not influence the transformer operation, and

- 15 Installation or removal of subsea power consuming devices can be done with the remaining parts of the subsea power distribution system in operation, e.g. during maintenance and/or repair.

Shutdown or disconnection of the entire transformer would have substantial operational concerns, e.g. loss of operational time and costs. The disclosed subsea power distribution device and system overcomes such shortcomings of related background solutions.

CLAIMS

1. Subsea AC power distribution device, comprising
a watertight housing accommodating at least one transformer, the transformer
having a primary winding and a plurality of secondary windings;
5 input terminals, electrically connected to the primary winding and arranged to be
connected to a remote AC power supply;
output terminals, electrically connected to the secondary windings and arranged to
be connected to subsea power consuming devices;
switches arranged to break the connections between each secondary winding and a
10 corresponding output terminal, the switches being arranged within the watertight
housing, wherein each switch includes a switch actuator and the watertight housing
is configured with a first compartment and a second compartment separate from the
first compartment, the transformer being arranged within the first compartment and
the switches being arranged in the second compartment.
- 15 2. Subsea AC power distribution device according to claim 1, wherein each
secondary winding is provided with a corresponding switch.
3. Subsea AC power distribution device according to claim 1 or 2, wherein the
first compartment and the second compartment are oil-filled.
4. Subsea AC power distribution device according to claim 3, wherein the
20 switch actuator is contained within the watertight housing.
5. Subsea AC power distribution device according to claim 4, wherein the
switch actuator is contained within the second compartment.
6. Subsea AC power distribution device according to claim 7, wherein the
switch actuator is arranged external to the watertight housing.

7. Subsea AC power distribution device according to claim 6, wherein the switch actuator actuates the switch by means of a mechanical shaft extending through a portion of the watertight housing.
- 5 8. Subsea AC power distribution device according to claim 6, wherein the switch actuator actuates the switch by means of a magnetic coupling over a portion of the watertight housing.
9. Subsea AC power distribution device according to any one of the preceding claims, wherein the switch actuator is connected to and arranged to be controlled by
10 a control unit which is arranged separately from the watertight housing.
10. Subsea AC power distribution device according to any one of the preceding claims, wherein the switch actuator is an electrical switch actuator.
11. Subsea AC power distribution device according to any one of the preceding claims, wherein the switch actuator is a hydraulic switch actuator.
- 15 12. Subsea AC power distribution device according to any one of the preceding claims, wherein each power consuming subsea device comprises a further power switch in a separate switch unit attached to or included in the same housing as the corresponding power consuming subsea device.
13. AC Subsea power distribution system, comprising
20 a remote AC power supply,
a subsea AC power distribution device according to one of the claims 1-12,
a plurality of subsea power consuming devices, and
primary electrical connections which interconnect the remote power supply and the input terminals of the subsea power distribution device, and
25 secondary electrical connections which interconnect the output terminals of the subsea power distribution device and the subsea power consuming devices.