environmental footprint by using cleaner energy systems such as fully electric systems or electric hybrid systems.

There is a need for increased capacity of sustainable energy for offshore and subsea equipment and vessels in the oil and gas industry.

Summary of the invention

Embodiments of the present invention seek to obviate or at least mitigate the foregoing limitations of existing offshore electrical energy technology.

Embodiments of the present invention also seek to provide a modular subsea energy storage system to provide electrical power for vessels, subsea equipment, vehicles and infrastructure.

Embodiments of the present invention further seek to provide a modular system with interchangeable components which may be configurable to different power requirements for specific applications.

Embodiments of the present invention also seek to provide an energy storage system comprising an energy management system to maximise life of batteries, control electrical loads, and provide data acquisition to surface.

It is amongst the aims of the claimed invention to provide a method and/or apparatus for subsea power storage and/or management that allows easy deployment and maintenance, that may be powered by renewable or non-renewable energy.

In particular, one aim of an example of the claimed invention is to provide a method and/or apparatus which may be configured or optimised to provide energy storage in proximity to the subsea location of use and thus minimise capital and operational expenditure.

Further aims of the claimed invention will become apparent from the following description.

According to a first aspect of the present invention, there is provided a modular system for the storage of energy subsea, the modular system comprising:

an energy management system;
a rechargeable subsea energy storage system;
wherein the energy management system is configured to control a transfer of electrical energy between the rechargeable energy storage system and at least one energy source and/or at least one electrical load; wherein the modular system is a bidirectional power transfer system.

The rechargeable energy storage system may be a subsea rechargeable energy storage system. One or more components or modules of the rechargeable energy storage system may be located subsea. One or more components or modules of the rechargeable energy storage system may be located on, at or above the surface of the water.

The rechargeable energy storage system may be a modular system. Preferably the rechargeable energy storage system is a rechargeable battery system. The rechargeable battery system may comprise at least one battery. The at least one battery may be located subsea. The rechargeable battery system may comprise a plurality of batteries. The rechargeable battery system may comprise two or more batteries. The number of batteries in the rechargeable battery system may depend on the desired energy capacity of the rechargeable battery system. The rechargeable battery system may comprise up to one hundred batteries. The rechargeable battery system may comprise more than one hundred batteries. The rechargeable battery system may comprise up to fifty batteries. The rechargeable battery system may comprise between ten and forty batteries. The rechargeable battery system may comprise thirty batteries. The capacity of the battery system may be up to 1 GWh. The capacity of the battery system may be in the range of 0.1MWh to 1 GWh. The capacity of the battery system may be in the range of 0.5MWh to 500 MWh. The capacity of the battery system may be up to 100MWh. The capacity of the battery system may be up to 15MWh. The rechargeable energy storage system may be based on lithium ion technology. The at least one battery may be a lithium ion battery. The at least one battery may be selected from the group comprising nickel-hydrogen, lithium-ion, lead-acid, and/or nickel-cadmium batteries. The two or more batteries may be arranged in a parallel or serial orientation.

Each battery may comprise at least one battery cell. Each battery may comprise two or more battery cells. Each battery may comprise a plurality of battery cells. Each battery may be a subsea retrievable unit. Two or more batteries may be arranged into a battery array. The battery array may be a subsea retrievable unit. Each battery may be provided in

by a user remotely. The energy management system may be an autonomous system or a semi-autonomous intelligent energy management system.

In this context, subsea means the modular system or at least one component or module of the modular system is located underwater or under the surface of a body of water such as the sea. The modular system is designed for the storage and/or distribution of energy underwater or under the surface of the sea.

There is disclosed a modular system for the storage of energy subsea, the modular system comprising:
an energy management system;
a first modular apparatus configured to be connected to at least one energy source
a second modular apparatus configured to be installed subsea;
wherein the second modular apparatus comprises rechargeable energy storage system;
wherein the first modular apparatus is configured to transfer power from the at least one energy source to the second modular apparatus;
wherein the energy management system is configured to control the transfer of electrical energy between the rechargeable energy storage system and at least one energy source and/or at least one electrical load.

The first modular apparatus may be mountable to the at least one energy source at, above or on the surface of a body of water or subsea. Preferably the first modular apparatus is a surface mountable first modular system.

The first modular apparatus may comprise a first support frame comprising a plurality of receptacles for mounting the functional modules of the surface mountable first modular system. The surface mountable first modular system may comprise functional modules selected from the group comprising: at least one AC transformer, at least one AC supply distribution board, at least one AC-DC converter; at least one DC supply. The first modular apparatus may be configured to be connected to the at least one energy source to convert alternating current provided by the at least one energy source to direct current. The first modular apparatus may be designed to be mounted to structures or apparatus of existing energy sources such as wind turbines to retrofit these installations.

The second modular apparatus may be configured to be installed and/or secured to a seabed. The second modular apparatus may be configured to be installed and/or secured on a bed of a body of water. The second modular apparatus may be configured to be suspended underwater above the seabed.

The second modular apparatus may comprise functional modules selected from the group comprising: at least one energy management system; at least one DC distribution board, at least one DC-DC convertor, at least one AC-DC convertor; at least one DC load distribution panel; at least one AC load distribution panel; and/or at least one battery. The subsea mountable second modular system may comprise a second support frame comprising a plurality of receptacles for mounting the functional modules of the subsea mountable second modular system. The second modular apparatus may be a subsea mountable second modular system. The second modular apparatus may be connected to the first modular apparatus by at least one cable or umbilical. The second modular apparatus may be configured to receive the direct current power supply provided by the first modular apparatus.

According to a second aspect of the present invention, there is provided a method of storing energy subsea, the method comprising:
providing a modular subsea energy storage system, the system comprising:
an energy management system;
a rechargeable subsea energy storage system; and
controlling a bidirectional transfer of electrical energy between the rechargeable energy storage system and at least one energy source and/or at least one electrical load.

The modular subsea energy storage system may be configured to be installed and/or secured to a seabed. The modular subsea energy storage system may be configured to be installed and/or secured on a bed of a body of water. The modular subsea energy storage system be configured to be suspended underwater above the seabed.

to quantify battery degradation with respects to its nominal state. The method may comprise estimating the state of health of one or more of the batteries. The method may comprise monitoring and/or predicting future environmental conditions. The method may comprise monitoring and/or predicting metocean, wind and/or solar conditions. The method may comprise identifying or studying trends and patterns on power requirement. The method may comprise creating a model or digital twin based on collected data. .

There is disclosed a method of distributing power from a modular subsea energy storage system, the method comprising:
providing a modular subsea energy storage system, the modular subsea energy storage system comprising:
an energy management system; and
a rechargeable energy storage system;
transferring electrical energy between the rechargeable energy storage system and at least one energy source and/or at least one electrical load.

The modular subsea energy storage system may be configured to be installed and/or secured to a seabed. The modular subsea energy storage system may be configured to be installed and/or secured on a bed of a body of water. The modular subsea energy storage system be configured to be suspended underwater above the seabed.

According to a third aspect of the present invention, there is provided a method of servicing a modular subsea energy storage system comprising:
providing a modular system; the modular system comprising:
an energy management system; and
a rechargeable subsea energy storage system;
wherein the energy management system is configured to control a bi-directional transfer of electrical energy between the rechargeable energy storage system and at least one energy source and/or at least one electrical load;
accessing a modular component of the modular system;
releasing the modular component from the modular system.

The modular system may be configured to be installed and/or secured to a seabed. The modular system may be configured to be installed and/or secured on a bed of a body of water. The modular system be configured to be suspended underwater above the seabed.

The method may comprise installing a replacement modular component on or in the modular system. The modular system may comprise a support frame. The modular system or at least one component of the modular system may be removably mounted on the support frame. The modular system mounted on the support frame may be configured to be installed and/or secured to the seabed. The modular system mounted on the support frame may be configured to be suspended underwater above the seabed. The support frame may comprise a plurality of receptacles for mounting functional modules on the support frame. The functional modules are selected from the group comprising: at least one AC transformer, at least one AC supply distribution board, at least one AC-DC converter; at least one DC supply, at least one energy management system module; at least one DC distribution board, at least one DC-DC convertor, at least one AC-DC convertor; at least one DC load distribution panel; at least one AC load distribution panel; and/or at least one battery.

The support frame may be a sealed frame. The support frame may be a pressurised compartment which may be fluidly sealed. The support frame may have a port and/or hatch associated with each of the receptacles. Each component of the system may be removed or installed through at least one port and/or hatch on the frame. Each functional module (component) of the system may be mounted into a receptacle by a quick connector.

The method may comprise accessing a receptacle on the support frame. The method may comprise releasing a functional module from the receptacle. The method may comprise accessing a receptacle through a hatch or port positioned above or adjacent to the receptacle. The method may comprise releasing a functional module from the receptacle manually or via a control module. The method may comprise installing a functional module in the receptacle. The method may comprise installing a functional module in a previously vacant receptacle.

There is disclosed a modular system for the storage of energy subsea, the modular system comprising:
a support frame comprising a plurality of receptacles for mounting functional modules on the support frame;
a plurality of functional modules comprising at least one energy management system and a plurality of rechargeable batteries.

There is disclosed an apparatus for the storage of energy at the bed a body of water, the apparatus comprising:
a support frame comprising a plurality of receptacles for mounting functional modules on the support frame; and
a plurality of functional modules comprising at least one energy management system and a plurality of rechargeable batteries;
and wherein the support frame and plurality of functional modules form an integrated assembly configured to be towed to an installation and/or lowered to the bed of the body of water.

There is disclosed a method of storing and managing energy on the bed of a body of water using the apparatus defined in the aspects and examples of the claimed invention.

There is disclosed a method of installing apparatus for the storage and management of energy on a bed of a body of water, the method comprising:
providing an apparatus comprising an integrated assembly having support frame and a plurality of functional modules mounted on the support frame;

wherein the plurality of functional modules comprises at least one energy management system and a plurality of rechargeable batteries;
and wherein the support frame and plurality of functional modules form an integrated assembly configured to be towed to an installation and/or lowered to the bed of the body of water.

The method may comprise connecting the apparatus to at least one energy source. The at least one energy source may be located on the surface or subsea. The method may comprise connecting the apparatus to at least one energy source by at least one cable or umbilical. The method may comprise connecting the apparatus to at least one electrical load.

There is disclosed a method of storing and managing energy on a bed of a body of water, the method comprising:
providing an apparatus comprising an integrated assembly having support frame and a plurality of functional modules mounted on the support frame;
wherein the plurality of functional modules comprises at least one energy management system and a plurality of rechargeable batteries;
lowering the integrated assembly to the bed of the body of water and locating the apparatus on the seabed;
operating the at least one energy management system to control a transfer of electrical energy between at least one of the rechargeable batteries and at least one energy source and/or at least one electrical load.

There is disclosed a modular system for the storage and/or distribution of energy subsea, the modular system comprising:
at least one an energy management system;
at least one rechargeable energy storage system;

wherein the at least one energy management system is configured to control a transfer of electrical energy between the at least one rechargeable energy storage system and at least one energy source and/or at least one electrical load.

The modular system may comprise two or more rechargeable energy storage systems. The at least one an energy management system may be configured to control a transfer of electrical energy between the two or more rechargeable energy storage systems. The at least one an energy management system may be configured to control a transfer of electrical energy between the two or more rechargeable energy storage systems and at least one energy source and/or at least one electrical load

Brief description of the drawings

There will now be described, by way of example only, various embodiments of the invention with reference to the drawings, of which:

Figure 1 is a diagram of a subsea energy storage and management system according to an embodiment of the invention;

Figure 2 is a schematic diagram showing components of a subsea energy storage and management system of Figure 1;

Figure 3A is a schematic diagram showing a surface mountable module system of a subsea energy storage system and management system according to an embodiment of the invention;

Figure 3B is a schematic diagram showing subsea mountable module system of a subsea energy storage system and management system configured to be connected to the surface mountable module system of Figure 3A;

Figure 4 is a schematic diagram showing components of the subsea energy storage and management system of Figure 1 with batteries mounted in separate frames; and

Claims

1. A modular system for the storage of energy subsea, the modular system comprising:
an energy management system;
a rechargeable subsea energy storage system;
wherein the energy management system is configured to control a transfer of electrical energy between the rechargeable energy storage system and at least one energy source and/or at least one electrical load; wherein the modular system is a bidirectional power transfer system.

2. The modular system according to claim 1 wherein the rechargeable energy storage system is a rechargeable battery system comprising at least one battery.

3. The modular system according to claim 1 or claim 2 wherein at least one component of the rechargeable energy storage system is a subsea retrievable unit.

4. The modular system according to any preceding claim wherein the energy pmanagement system is configured to control a transfer power between the at least one energy source and/or at least one electrical load to the rechargeable energy storage system to charge or partially charge the rechargeable energy storage system.

5. The modular system according to any preceding claim wherein the energy management system is configured to control a transfer power between the rechargeable energy storage system and the at least one energy source and/or at least one electrical load.

6. The modular system according to any preceding claim wherein the energy management system is configured to control a state of charge of the rechargeable energy storage system.

7. The modular system according to any preceding claim wherein the at least one energy source is selected from the group comprising a renewable energy source, a non-renewable energy source, an electrical grid, at least one turbine, at least one vessel, at least one onshore substation, at least one offshore substation, at least one wave energy converter, at least one tidal energy converter, at least one ocean

current energy converter, at least one ocean thermal energy converter and/or at least one solar panel system.

8. The modular system according to any preceding claim wherein the at least one energy source is located at, above and/or below the surface of the sea.

9. The modular system according to any preceding claim wherein the at least one electrical load is selected from the group comprising an electrical grid, a wind farm grid, underwater autonomous vehicles, vessel, remotely operated vehicle, electrolysers, hydrogen electrolysers, Christmas trees, well control packages, subsea hydraulic power units, subsea service modules, subsea pump and/or subsea test trees.

10. The modular system according to preceding claim wherein the system comprises at least one functional module selected from the group comprising: at least one AC transformer, at least one AC supply distribution board, at least one AC-DC converter; at least one DC supply, at least one energy management system; at least one DC distribution board, at least one DC-DC convertor, at least one AC-DC convertor; at least one DC load distribution panel, at least one AC load distribution panel; and/or at least one battery.

11. The modular system according to any preceding claim wherein the system comprises a surface mountable first modular system and a subsea mountable second modular system.

12. The modular system according to claim 11 wherein the surface mountable first modular system is configured to be connected to the at least one energy source to convert alternating current provided by the at least one energy source to direct current.

13. The modular system according to claim 11 or 12 wherein the subsea mountable second modular system is configured to receive direct current power supply provided by the surface mountable first modular system.

14. The modular system according to any preceding claim wherein the modular system comprises a support frame, wherein the modular system or at least one component of the modular system is removably mounted on or to the support frame.

15. The modular system according to claim 14 wherein the modular system mounted on the support frame is configured to be installed and/or secured to the seabed.

16. The modular system according to any preceding claim wherein the energy management system is configured to collect and/or transmit data to surface.

17. The modular system according to any preceding claim wherein the energy management system is configured to collect and/or monitor data selected from the group comprising energy usage, individual battery status, individual battery health, temperature, operational data, toxic impurities, humidity, water ingress, internal pressure, capacity fade, power fade status of circuit breakers, on/off/tripped status of components, electrical parameters of a distribution board or an enclosure; weather conditions, and/or environmental conditions,

18. The modular system according to any preceding claim wherein the system is an autonomous system or a semi-autonomous system.

19. A method of storing energy subsea, the method comprising:
providing a modular subsea energy storage system, the system comprising:
an energy management system;
a rechargeable subsea energy storage system; and
controlling a bidirectional transfer of electrical energy between the rechargeable energy storage system and at least one energy source and/or at least one electrical load.

20. The method according to claim 19 comprising transferring electrical energy from the at least one energy source and/or at least one electrical load to the rechargeable energy storage system to charge or partially charge the rechargeable energy storage system.

21. The method according to claim 19 or 20 comprising managing the transfer of electrical energy from the rechargeable energy storage system to at least one energy source and/or at least one electrical load.

22. The method according to any preceding claim comprising controlling the transfer of electrical energy between the rechargeable energy storage system and at least one energy source and/or at least one electrical load based on operation schedule, maintenance work, installation work, electrical load power requirements, energy source power requirements; environmental conditions, weather conditions and/or predicted weather conditions.

23. A method of servicing a modular subsea energy storage system comprising:
providing a modular system; the modular system comprising:
an energy management system; and
a rechargeable subsea energy storage system;
wherein the energy management system is configured to control a bi-directional transfer of electrical energy between the rechargeable energy storage system and at least one energy source and/or at least one electrical load;
accessing a modular component of the modular system;
releasing the modular component from the modular system.

24. The method according to claim 23 comprising installing a replacement modular component on or in the modular system.