Submersible Data Centre Mountable On A Submersible Platform

Field of Invention

[001] The present invention relates to a submersible data centre. The submersible data centre is configured in a water-tight capsule or capsules and is/are mounted on a submersible platform of an elevator apparatus, which is being deployed in a body of water; the data centre can thus be submerged under water for operation or be winched up above the water for retrieval or maintenance.

Background

[002] A data centre includes networks of electronic systems for remote storing, processing, and distributing of large amounts of data; as a result, a lot of heat is generated. Data centres housed on land use ventilation and air-conditioning systems. With fast-growing demand for cloud-based data services, the challenges for these data centres may be faster processing speeds, lower operating costs (including electric power consumption), security, and so on.

[003] A National Environment Authority in Singapore did a study in 2012 on 23 data centres in Singapore found that the average power usage effectiveness was 2.07; this indicates the total power requirements (cooling and IT load) are higher than other IT load by 107%; this points to inefficient electric power usage. Another study that year found the total electric power consumed by these data centres was 7.2% of Singapore's total electrical power consumption. The energy consumption rate of data centres is expected to increase to 12% by 2030, if conventional technologies continue to be used.

[004] Ventilation and air-conditioning may make up half of the electricity consumption for operating a data centre. Locating data centres in a body of water for cooling purposes or for using green energy produced in offshore farms have been sought. For eg., US Patent No. 8,853,872, assigned to Google, Inc., describes a floating platform or a ship carrying modular data centers, which are powered from electricity produced by the motion of wave powered generators, and are cooled by cooling water pumped by wave-powered generators. The modular data centers may be configured in shipping containers.

[005] In another approach, US Patent No. 10,136,562, assigned to Fujitsu, describes a data center located in a housing member that is disposed under water. A heat exchanger discharges heat from the data center to the surrounding water. An opening is formed in a bottom face of the housing member and a liquid film covers a liquid surface of the water in the opening, through which a workman makes access into the housing member.

[006] In another approach, US Patent No. 10,285,309, assigned to Microsoft, describes datacenter modules are installed on the floor of a body of water; the data centers can also be anchored to the floor or be mounted on a platform that sinks to the floor of the body of water.

[007] In yet another approach, patent publication WO2020/055330, by Keppel Data Centre, describes a floating data centre park serviced by a near-shore pier, a power supply module and chilled water pipes.

[008] It can thus be seen that there exists a need for another type of underwater submersible data centre that has advantages over known underwater systems. Desirably, this submersible data centre is easy to deploy, operate and maintain.

Summary

[009] The following presents a simplified summary to provide a basic understanding of the present invention. This summary is not an extensive overview of the present invention, and is not intended to identify key features of the invention. Rather, it is to present some of the inventive concepts of this invention in a generalised form as a prelude to the detailed description that is to follow.

[0010] The present invention seeks to provide a submersible data centre capsule or data centre capsules mountable on a submersible platform of an elevator apparatus. A plurality of the elevator apparatus can be organized together and the data centre capsules are operable like a data centre farm. In addition, some of the data centre capsules may be used to support parallel supercomputing, data mining (including, crypto-currency mining), and so on.

[0011] In one embodiment, the present invention provides a submersible data centre mountable on an elevator apparatus, as defined in the claims.

[0012] In another embodiment, the present invention provides a method for operating an underwater data centre, as defined in the claims.

Brief Description of the Drawings

[0013] This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

[0014] FIGs. 1-2 illustrate a submersible data centre located on a submersible platform of an elevator apparatus according to an embodiment of the present invention, whilst FIG. 3 illustrates an upper part of the submersible platform and FIGs. 4-5 illustrate an upper part of the elevator apparatus;

[0015] FIGs. 6-8 illustrate a first-time deploying of the elevator apparatus at an installation site in a body of water;

[0016] FIGs. 9-11 illustrate submerging the submersible platform in the body of water after the first-time deployment;

[0017] FIGs. 12-14 illustrate use of power arrangements during the first-time deployment, launching of the elevator apparatus and operating the data centre;

[0018] FIGs. 15-17 illustrate various ways of arranging the data centre capsules on or partially inside the submersible platform;

[0019] FIG. 18 illustrates use of a heat-exchanger or chiller to dissipate thermal energy from a data centre to the surrounding; FIG. 19 illustrates heat-exchange between a data centre and water inside and outside the submersible platform; and FIG. 20 illustrates a centralized chiller cooling system;

[0020] FIGs. 21-23 illustrate arrangements of two fail-safe brakes on the support legs; and

[0021] FIG. 24 illustrates part of a submersible data centre located on a submersible platform according to another embodiment.

Detailed Description

[0022] One or more specific and alternative embodiments of the present invention will now be described with reference to the attached drawings. It shall be apparent to one skilled in the art, however, that this invention may be practised without such specific details. Some of the details may not be described at length so as not to obscure the present invention.

[0023] FIGs. 1-2 show an elevator apparatus **100** in which a plurality of underwater data centres **180** are mounted on a submersible platform **110**; these data centres **180** are configured in water-tight capsules, which allow modularity and portability; for illustration, 3 data centre capsules **180** are shown in FIG. 1. The submersible platform **110** is supported on 3 support legs **130** after the elevator apparatus **100** is being deployed in a body of water; the submersible platform **110** is operable to slide relative to the support legs **130** by winches **132** mounted on top of each support leg **130**. Located above each winch **132**, is a power generator **160** to supply electric power to the elevator apparatus **100**, the data centres **180**, winches **132**, lightings, associated control panels and so on. During operation, the top parts of the support legs **130**, the winches **132** and the power generators **160** are located above a water level, as shown in FIG. 2. The distal end of each of the support leg **130** terminates with a spudcan **170**, so that the spudcans **170** with an enlarged sectional area can settle or be embedded stably in a waterbed at the bottom of the body of water to support the entire elevator apparatus **100** after installation. It is possible that this elevator apparatus **100** can be moved or relocated to a new site for re-installation, if there is such a need.

[0024] The submersible platform **110** is fabricated from plates to form a substantially outer box-shaped structure and a hollow, interior structure. The hollow, interior may form buoyancy or ballast tanks; these tanks may be equipped with pumps and can be flooded with water for ballasting, water can be discharged for raising the submersible platform or

to create water flow for dissipating heat energy with a heat exchanger **190** (as seen in FIG. 19). Sleeves **140** forming part of the submersible platform around the support legs allow the submersible platform **110** to slide relatively to the support legs **130**. In other embodiments, wear or bearing strips (not shown in the figures) are located in the sleeves **140** to provide smoother sliding motion. It is also possible to provide a lower part of each of the sleeves **140** with a tapered surface **slot 232**,**232a** and a matching wedge member **233**,**233a** connected to a linear actuator **235**,**235a**; the assembly of the sleeve **140** with tapered surface slot, matching wedge member and linear actuator provide fail-safe brake mechanisms **200**,**200a** to stop relative sliding of the submersible platform **110** on the support legs **130** during an abnormal event; the fail-safe brakes **200**,**200a** may operate in conjunction with a motion sensor or motion sensors 324 to monitor normal sliding speed of the sleeves **140** on the support legs **130**; the fail safe brakes **200**,**200a** will be further described in FIGs. 21-23. Referring back to FIGs. 1-2, the submersible platform **110** is located removeably onto the support legs **130** by locating pins **144** at two levels or positions – above water and at a submerged level; this is more clearly seen in FIG. 2. The locating pins **144** go through holes **142** formed on the sleeves **140** and locating holes **146**,**150** formed on the support legs **130**, so that the submersible platform **110** is connectable to the support legs **130** at either of the two levels. A range of the locating holes **146**,**150** are provided to allow for varied settling or embedding of the spudcans **170** into the waterbed.

[0025] Located on the submersible platform **110** are 3 leg-lowering winches **112**; this is more clearly shown in FIG. 3, and the numbers of leg-lowering winches **112** match the number of support legs **130**. The leg-lowering winches **112** are used only once for deploying the support legs **130** after the elevator apparatus **100** has been towed to the installation site. As seen in FIGs. 1-3, wire ropes **L2** from the leg-lowering winches **112** pass through each associated sheave block **114** before terminating at a padeye **138** located near the distal end of each of the support legs **130**. Each wire rope **L2** is selected to withstand safely more than the weight of each support leg **130**. Back to the winch **132** located at the top of the support legs, the associated wire ropes **L1** pass through each associated winch sheave **136** before terminating at a padeye **134** located on the submersible platform **110**. Each wire rope **L1** is selected to withstand safely more than the weight of the weight of the submersible platform **110**. For access, each of the winches **132** and

generators **160** are equipped with a respective service platform **133**, **162**, and this is more clearly shown in FIGs. 4-5.

[0026] FIG. 6 shows another view of the elevator apparatus **100** with the submersible platform **110** being located near the top of the support legs **130**. FIG. 7 schematically shows a first-time deploying of the support legs **130** after the elevator apparatus **100** is towed to the installation site, with the support legs **130** remaining extended substantially above the submersible platform, whilst the submersible platform **110** is floating on the water. To lower or deploy the support legs **130**, the leg-lowering winches **112** release the wire ropes **L2** and allow the support legs **130** to lower down to the waterbed in a controlled manner. After the leg-lowering winches **112** have released the support legs, deadweights of the support legs cause the spudcans **170** to lodge into the waterbed, as can be visualised from FIG. 8. From this point onwards, the leg-lowering winches **112** are no longer required; it is possible that the leg-lowering winches **112** are disabled or arranged to be dismantled from the elevator apparatus **100**, so as to accommodate additional data centre capsules **180**. During the first-time deploying of the support legs, electric power is supplied from a barge that has towed the elevator apparatus **100** to the installation site, as indicated in FIG. 12, or from a separate power supply barge.

[0027] After the spudcans **170** have settled stably into the waterbed, the generators **160** located at the top of the support legs **130** are operated to supply electric power to the elevator apparatus **100**. Inside an upper part of each support leg **130**, a compartment **164** is provided to store fuel for the respective generator **160**. To ensure further stability of the spudcans on the waterbed, the winches **132** are operated to elevate the submersible platform **110** partially or completely above the water level. This helps to preload or to expedite the spudcans **170** settle stably into the waterbed. FIG. 9 shows the support legs **130** after settling into the waterbed and the submersible platform **110** is winched above the water level. To lower down the submersible platform **110** to an operation position, schematic FIGs. 10-11 show the winches **132** release the wire ropes **L1** in a controlled manner to submerge the submersible platform **110** into the body of water. In addition, water may also be pumped into the ballast tanks formed inside the submersible platform **110** to sink the submersible platform. After, the submersible platform **110** has reached the second level or position at the lower ends of the support legs **130**, the locating pins **144** are put into place to locate the submersible platform to the support legs **130**. When the data

centre capsules **180** are scheduled to be floated up, the reverse processes of removing the locating pins **144**, winching up the submersible platform **110** and releasing the ballast water are carried out until the submersible platform **110** reaches the first level or position near the top of the support legs **130**; the locking pins **144** are then put into place to locate the submersible platform **110** onto the support legs **130** at the first level.

[0028] As described above, during initial, first-time deployment of the support legs **130**, the barge supplies electric power to operate the leg-lowering winches **112** until after the elevator apparatus **100** is stably supported on the waterbed, as seen in FIG. 12. FIG. 13 shows that after the elevator apparatus **100** is stably installed at the site, the power generators **160** are operated to supply electric power, for example, to operate the winches **132**, associated controls and so on, through a control board (not shown in the figures). In other embodiments, it is possible that after installation of the elevator apparatus **100**, the data centre capsules **180** are powered from an onshore power supply (for example, via submarine cables) through a grid connection **165**; it is also possible to supply green energy to the elevator apparatus **100** from an offshore farm operable by solar power, wind, tides and/or wave forces, as seen in FIG. 14. It is also possible that the power generators **160** are employed to power the data centre capsules **180**,**180a** for an interim period during an emergency operation when the onshore or offshore power supply is interrupted.

[0029] FIG. 14 further shows a short-break load connection **184** and a non-short-break load connection **185** from a switchboard **183** located inside each data centre capsule **180**. The short-break load connection supplies electric power to components (such as, fans, pumps, compressors, etc.) that can be temporarily interrupted, for example, for substantially 5 – 15 minutes. The non-short-break load connection **185** supplies power to servers and equipment via an uninterrupted power supply (UPS) **186** and a battery **187**. In practice, multiple UPS **186** and batteries **187** are provided, for eg. for hot swapping or redundancy or fail-safe operation.

[0030] FIGs. 15-17 show various ways of configuring the data centre capsules **180**,**180a** on the submersible platform **110**. In FIG. 15, the data centre capsules **180** are mounted onto the submersible platform, substantially horizontally, for example, on pedestals **181** with removeable fixing connectors **182** including screws, bolts and nuts, clamps and so on. In FIGs. 16-17, the data centre capsules **180a** are mounted substantially vertically and

partially embedded into the submersible platform **110**, for example, again with removable fixing connectors **182**, including screws, bolts and nuts, clamps and so on. These removable fixing connectors **182** allow the data centre capsules **180**,**180a** to be removed, for example, for replacement or for maintenance. As described above, the data centre capsules **180**,**180a** are located in water-tight capsules; preferably, these capsules have generally convex surfaces and are not restricted by the shapes illustrated in the figures; other shapes can be part-dome, part-spherical or part-oval, to capitalize on compression stresses induced on such capsules when being submerged under-water. The data centre capsules **180**,**180a** are also selected with substantially streamlined profiles or being arranged so as to reduce wave force loadings.

[0031] FIG. 18 shows a use of the heat exchanger **190** connected to a data centre capsule **180**,**180a** to dissipate heat from inside the data centre capsule to the surrounding body of water. The heat exchanger **190** includes fan coils that recirculate air inside the data centre capsules **180**,**180a** and exchanging heat energy through coils and water pumps to the surrounding water. In another embodiment, a refrigerated chiller unit **190a** is used to cool each data centre capsule **180**,**180a**. The refrigerated chiller unit **190a** includes an evaporator located inside a part of the data centre capsule **180**,**180a** and a condenser located outside the data centre. Refrigerant transfers heat from inside the data centre capsule through the evaporator and condenser, and discharges the heat to the surrounding water. It is possible that the insides of the data centre capsules are filled with nitrogen, a gas and not just air for cooling the equipment contained therein. It is also possible that heat sinks are mounted directly on the data centre equipment and heat is dissipated away by convection of nitrogen, gas or air to the fan coil of the heat exchanger **190** or chiller **190a**, thus providing direct cooling at the mounted heat sinks. It is also possible that server racks and the data centre equipment inside the data centre capsules are mounted on cold plates which are supplied internally with a dielectric cooling fluid (such as that supplied by Fluorinert Electronic Liquid, glycol, water, hydrocarbon fluid, etc.), which dielectric cooling fluid is then thermally connected to the heat exchanger **190** or chiller **190a** to provide another form of direct cooling.

[0032] When the data centre capsules **180a** are located partially inside the submersible platform **110** (as seen in FIGs. 16-17), FIG. 19 shows an arrangement of the heat exchangers **190** exchanging heat energy with the water inside the submersible platform

110; pumps may circulate the water inside the submersible platform **110** with cooler surrounding water, as schematically shown by arrows in FIG. 19. In another embodiment, chillers **190a** are used to transfer heat from inside the data centre capsules to the surrounding water. In yet another embodiment, a centralized chiller **190b** is used, as illustrated in FIG. 20; chilled fluid (such as, water) is supplied through a supply pipe to each data centre capsule **180**,**180a** and heat is transferred out through a return pipe to the centralized chiller **190b**.

[0033] With the above elevator apparatus **100**, the data centre capsules **180**,**180a** can be deployed in any body of water, including a lake, river, sea or ocean. An advantage of deploying the data centre capsules below the water is to dissipate heat energy to a large body of water. The elevator apparatus **100** allows quicker deployment for operating the data centre capsules or quicker retrieving of the data centre capsules (for operation or maintenance) than known underwater systems. Operating the data centre capsules at a depth near the waterbed provides additional access security; in addition, in some installations, water currents near the waterbed may be calmer. It is also possible to provide surveillance cameras above and/or underwater to provide additional access security. Deploying the data centre capsules **180**,**180a** to a body of water also frees up valuable land for other uses.

[0034] FIGs. 21 and 23 show two variations of the fail-safe brakes **200,200a**. In Figs, 21 and 23, four wedge members **233,233a** are used to illustrate the fail-safe brakes **200,200a** but the numbers are not so restricted. In FIG. 21, the wedge members **233** are operable to slide on the respective slot surfaces **232** by the linear actuator **235**, with the connector **237** connecting the linear actuator **235,235a** to the respective wedge members **233,233a**; in one embodiment, the linear actuator **235** is equipped with an internal spring **236** that extends the linear actuator **235** during abnormal operation, such as, during a power failure or abnormal sliding of the platform **110** on the support legs **130**. During normal operation, the linear actuator **235** is retracted and the fail-safe brake **200** becomes non-operative. FIG. 22 shows a view of the fail-safe brake **200** in the axial direction along the support leg **130**. In FIG. 23, wedge members **233a** and the respective slot surfaces **232a** are inclined differently from the above, and the linear actuator **235a** are thus retracted to activate the fail-safe brake **200a** during abnormal operation; in one embodiment, the linear actuator **235a** is equipped with an internal spring **236a** at the rod side to retract when not being

actuated. If the internal springs **236**,**236a** are not used, then the linear actuators must be accordingly actuated during fail-safe braking, for eg., as assisted by fluid pressure accumulators and fluid brake valves.

[0035] FIG. 24 shows a part of an elevator apparatus **100a** with a submersible platform **110a** being supported by a single support leg **130a** according to another embodiment. FIG. 24 is used for illustration and does not show the winches to launch the support leg **130a** or to slide the platform **110a** on the support leg **130a**. The winches, wire ropes and other components described above are applicable on the elevator apparatus **100a**. However, for illustration, the platform **110a** is circular in outline and supports some data centre capsules **180c**, which may be similar to or different from the above data centre capsules **180,180b**.

[0036] In use of the above described data centres, it is possible that a data centre capsule **180**,**180a**,**180b** is employed as a digital twin to backup contents of an associated data centre capsule, for eg. for purposes of data security. With the digital twin, it is now possible to compare and to monitor the health of each of the data centre. In addition, the data centre capsules **180**,**180a**,**180b** are equipped with a thermal management artificial intelligent (AI) module **310** to monitor the temperature profiles of the data centre equipment; the thermal management AI module **310** can thus be used to intelligent distribute cooling liquids or refrigerants for improving thermal efficiency and efficiency of the cooling loads; the thermal management AI module **310** can also be used to generate preventive maintenance of the data centre equipment.

[0037] In another embodiment, a structural model of the elevator apparatus is created to monitor structure integrity and maintenance. For eg., strain sensors **322** are located at strategic locations on the elevator apparatus **100**,**100a**, motion sensors **324** at the fail-safe brakes, sensors **326** at the winches, environmental sensors **328** (such as, for wind and wave forces), fuel sensors **330** located in the fuel compartments **164**, and other allied sensors, etc., are connected to a structural artificial intelligent (AI) module **320**, which provides structural monitoring, safe operating or preventive maintaining of the elevator apparatus **100**,**100a**.

[0038] While specific embodiments have been described and illustrated, it is understood that many changes, modifications, variations and combinations of variations disclosed in

the text description and drawings thereof could be made to the present invention without departing from the scope of the present invention. For eg., the submersible platform **110** and the support legs **130** may be fabricated as latticed-structures without affecting the structural strengths or the above-described functionalities. In addition, the support legs **130** need not be circular in cross-section, it can be triangular or polygonal in cross-section; the number of support legs **130** is also not restricted to 1 or 3 numbers, as illustrated above; similarly, the submersible platform **110** can be of any shape in outline. Whilst the elevator apparatus **100** has been described, it is possible to install a plurality of the elevator apparatuses together, for example, and are organized like a data centre farm or park.

CLAIMS:

1. A submersible data centre mountable on an elevator apparatus comprising:

a submersible platform operable to slide relatively on a support leg or a plurality of support legs;

a data centre capsule mounted on or mounted partially inside the submersible platform; and

a winch located near a top end of each of the support leg or plurality of the support legs;

wherein the winches are operable to hoist or to lower the submersible platform between a first position located near an upper end of the support leg or plurality of the support legs that is above a water level and a second position located near a distal end of each of the support leg or plurality of the support legs, so that the data centre capsule is operational when the submersible platform at the second position is submerged in a body of water.

2. The apparatus according to claim 1, further comprising locking pins that are operable to engage into cooperating holes formed on both the submersible platform and the support leg or the plurality of support legs to locate the submersible platform on the support leg or the plurality of support legs at the first or the second position.

3. The apparatus according to claim 1 or 2, further comprising a generator located above each of the winches to supply electric power to the elevator apparatus.

4. The apparatus according to any one of claims 1-3, further comprising a leg-lowering winch associated with the support leg or each of the plurality of the support legs, wherein the leg-lowering winches are located on the submersible platform and are operable for a first-time deployment of the support leg or support legs into a waterbed at the bottom of the body of water.

5. The apparatus according to any one of claims 1-4, further comprising a spudcan disposed at a distal end of the support leg or each of the plurality of the support legs, with the spudcans allowing the support leg or plurality of the support legs to settle stably into the waterbed and to support the elevator apparatus.

6. The apparatus according to any one of the preceding claims, further comprising a heat exchanger, a chiller or a centralized chiller for dissipating heat energy from inside the data centre capsule to a surrounding water.

7. The apparatus according to claim 6, wherein the data centre capsule further comprises a thermal management artificial intelligent module to monitor a temperature profile inside each data centre and to distribute cooling fluids or refrigerants to the heat exchanger, chiller or centralized chiller for improved cooling efficiency.

8. The apparatus according to any one of the preceding claims, wherein the data centre capsule is removeably mounted onto the submersible platform by fixing connectors.

9. The apparatus according to any one of the preceding claims, wherein the submersible platform is configured with sleeves to guide sliding motion with the respective support legs, and wherein each of the sleeves is formed with a tapered slot surface matching a wedge member to provide a fail-safe brake mechanism.

10. The apparatus according to claim 9, further comprising a motion sensor located near the fail-safe brake, wherein during detection of an abnormal speed of sliding, the motion sensor is configured to activate the fail-safe brake to stop sliding of the submersible platform on the respective support leg or support legs.

11. The apparatus according to any one of the preceding claims, further comprising:

a structural artificial intelligent module, to which strain sensors, leg motion sensors, winch sensors, environment sensors are connected thereto for structural integrity monitoring, safe operating and/or preventive maintenance.

12. A method for operating an underwater data centre comprises:

locating a data centre capsule on an elevator apparatus, which is configured with a submersible platform; and

operating the submersible platform to slide on a support leg or plurality of cooperating support legs between a first position located near an upper end of the support leg or plurality of the support legs that is above a water level and a second position located

near a distal end of each of the support leg or plurality of the support legs, so that the data centre capsule is operational when the submersible platform at the second position is submerged in a body of water.

13. The method according to claim 12, wherein operating the submersible platform to slide on the plurality of cooperating the support legs comprises hoisting or lowering the submersible platform with a winch located at a top of the support leg or each of the plurality of the support legs, and at the first position or the second position, locating the submersible platform on the support leg or plurality of the support legs with a plurality of locking pins.

14. The method according to claim 12 or 13, further comprises transferring heat energy from an inside of the data centre capsule to the surrounding body of water with a heat exchanger, a chiller or a centralized chiller.

15. The method according to any of claims 12-14, further comprises disposing a leg-lowering winch associated with the support leg or each of the plurality of the support legs, wherein the leg-lowering winche(s) is/are operable for a first-time to deploy the plurality of the support legs into a waterbed at the bottom of the body of water.

16. The method according to claim 15, further comprises:

towing the elevator apparatus to an installation site with a barge; and

supplying electric power from the barge to controllably operate the leg-lowering winche(s) for the first-time deploying of the support leg or plurality of the support legs.