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(54) TRUSS CABLE SEMI-SUBMERSIBLE FLOATER FOR OFFSHORE WIND TURBINES AND CONSTRUCTION METHODS

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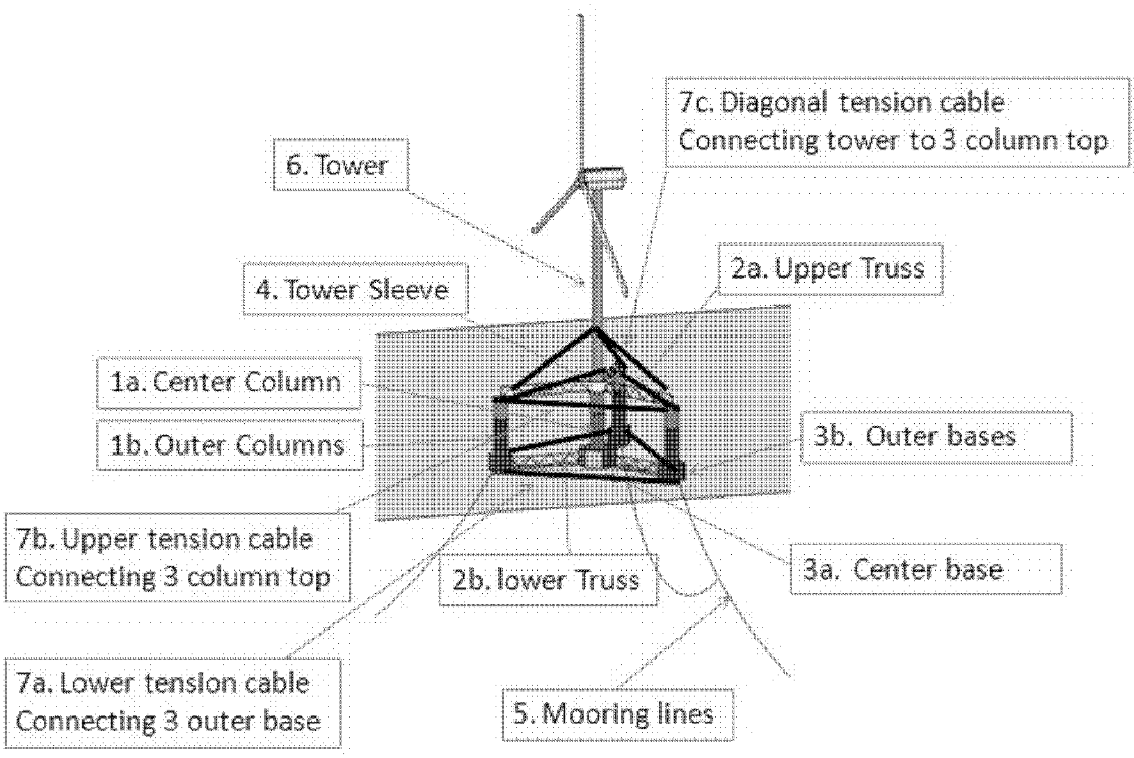
B63B 21/50 (2006.01)

(52) **U.S. Cl.** **114/265**

(57) **ABSTRACT**

Truss cable semi-submersible floater for offshore wind turbines and construction methods are provided. A floating system includes a hull, a tensioned cable system, and a tower. The hull includes vertical buoyant columns with one column at the center of the pattern, larger size column base tanks, and a truss system, all of which are coupled to each other for supporting the tower and wind turbines. The column can be made of hybrid materials, including steel and composite-concrete. The steel section and the composite-concrete section of the column can be connected by grouting. The tensioned cable system including upper, lower, and diagonal tensioned cables to connect the column, the column base, and the tower to reduce the bending moments and improve stability, strength and dynamic performance of the hull structure.



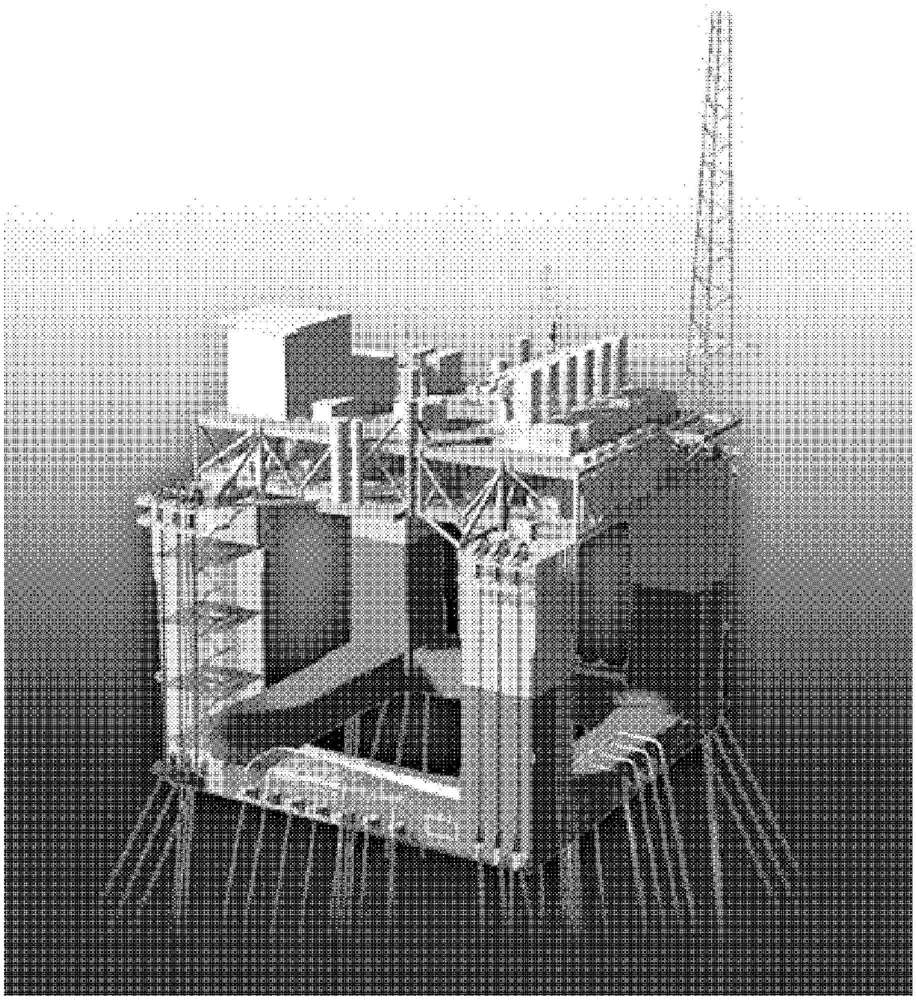


FIG. 1

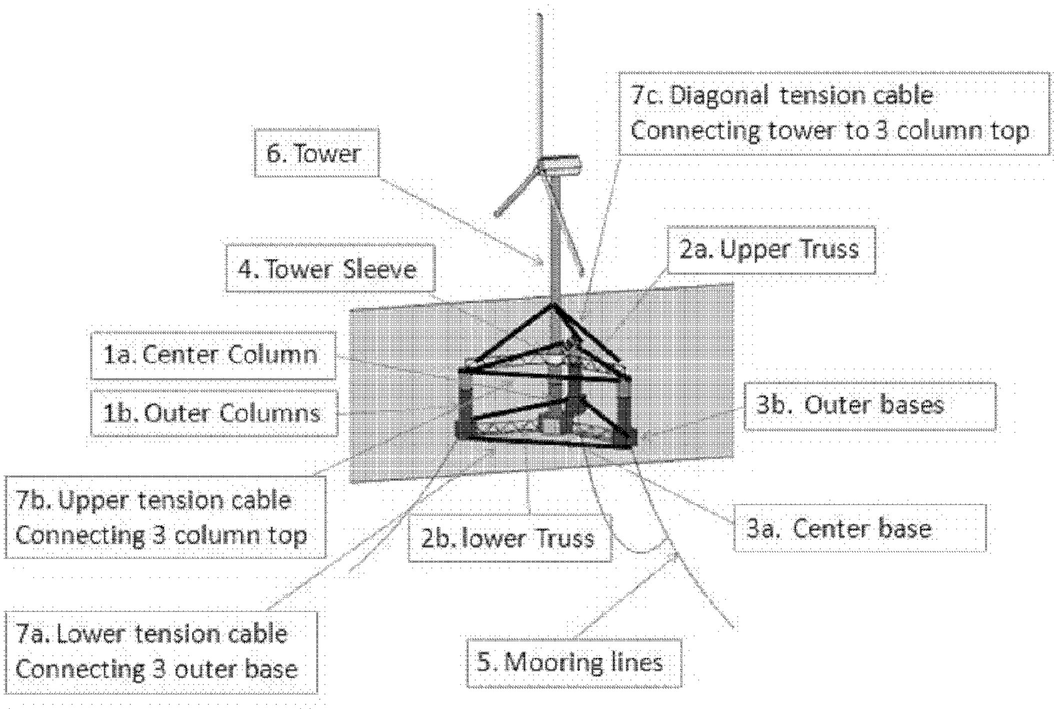

7c. Diagonal tension cable
Connecting tower to 3 column top
6. Tower
2a. Upper Truss
4. Tower Sleeve
1a. Center Column
1b. Outer Columns
3b. Outer bases
7b. Upper tension cable
Connecting 3 column top
2b. lower Truss
3a. Center base
7a. Lower tension cable
Connecting 3 outer base
5. Mooring lines

FIG. 2

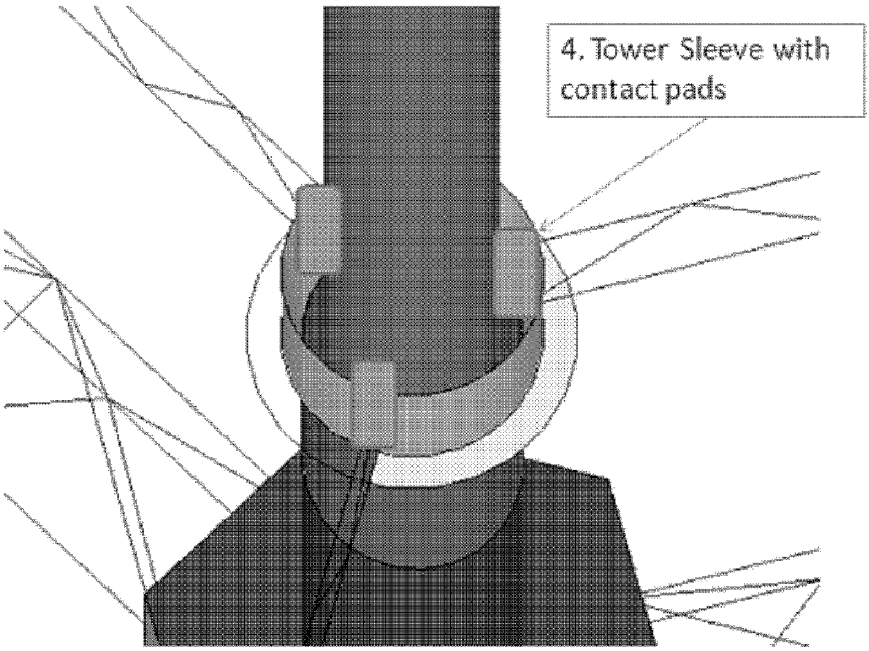


FIG. 3

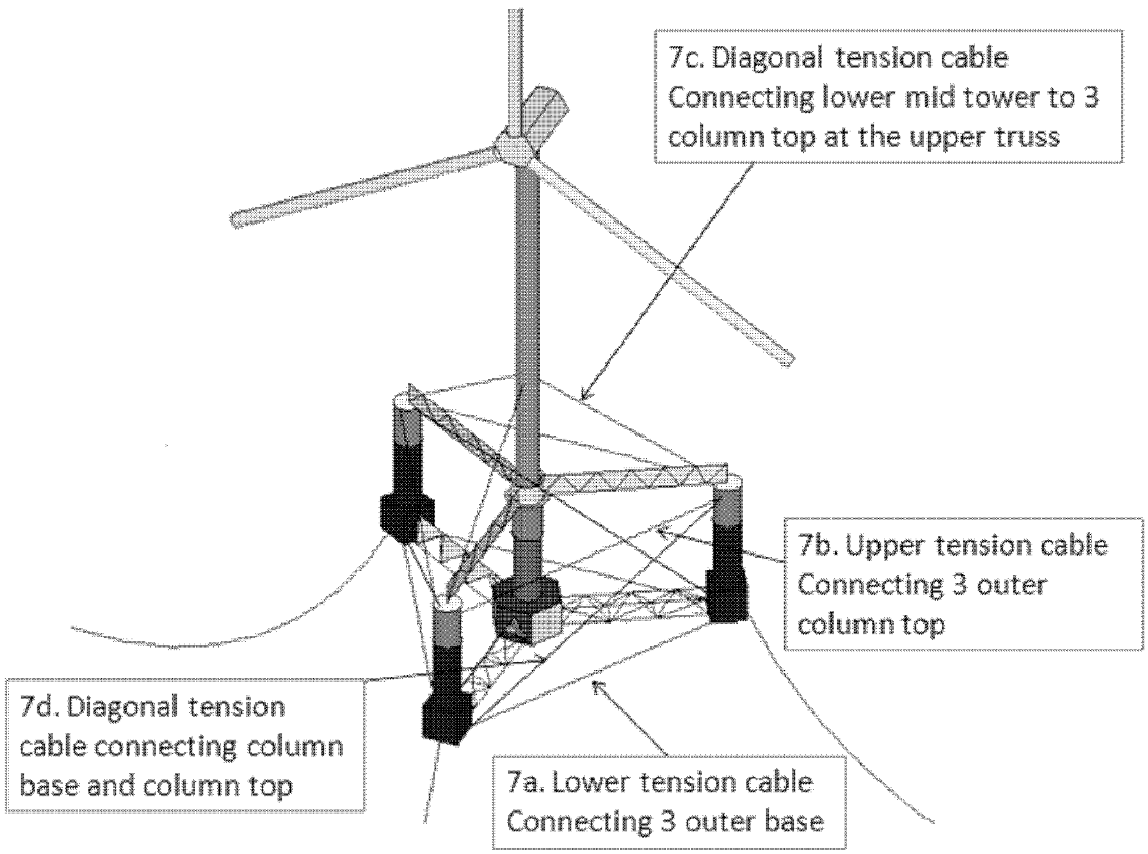

7c. Diagonal tension cable
Connecting lower mid tower to 3
column top at the upper truss
7b. Upper tension cable
Connecting 3 outer
column top
7d. Diagonal tension
cable connecting column
base and column top
7a. Lower tension cable
Connecting 3 outer base

FIG. 4

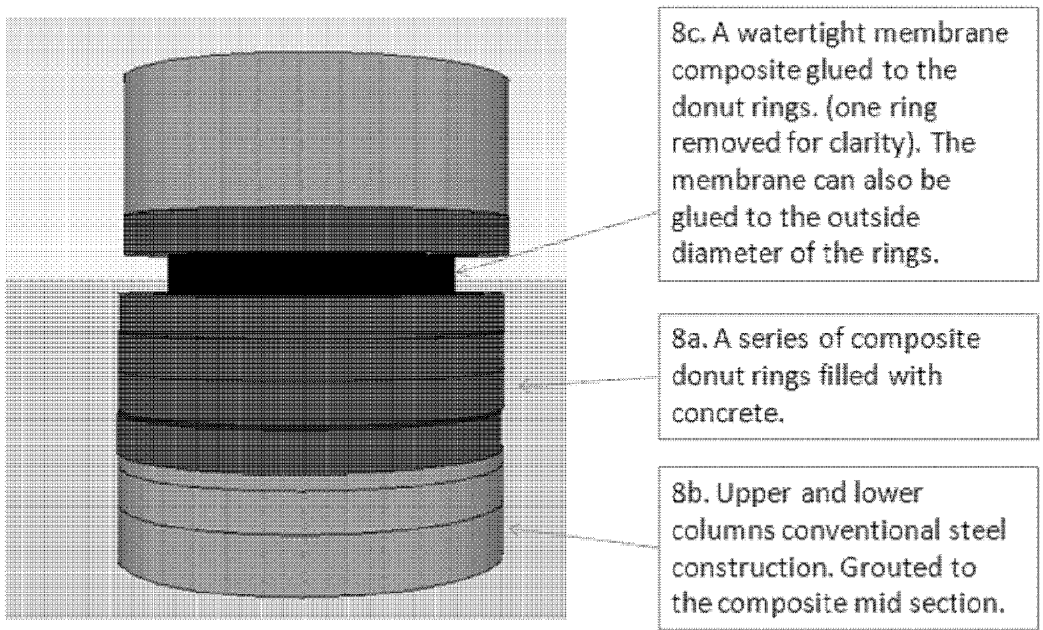

8c. A watertight membrane composite glued to the donut rings. (one ring removed for clarity). The membrane can also be glued to the outside diameter of the rings.
8a. A series of composite donut rings filled with concrete.
8b. Upper and lower columns conventional steel construction. Grouted to the composite mid section.

FIG. 5

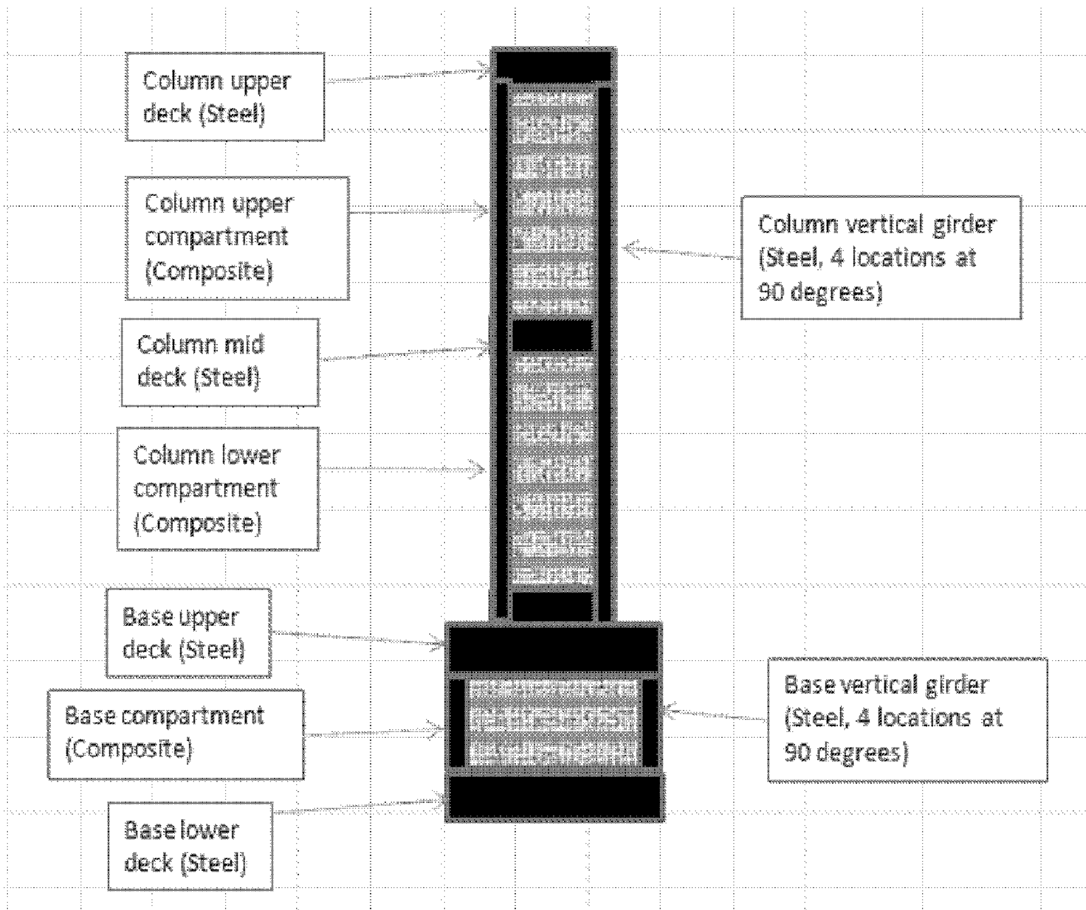

Column upper deck (Steel)
Column upper compartment (Composite)
Column vertical girder (Steel, 4 locations at 90 degrees)
Column mid deck (Steel)
Column lower compartment (Composite)
Base upper deck (Steel)
Base compartment (Composite)
Base vertical girder (Steel, 4 locations at 90 degrees)
Base lower deck (Steel)

FIG. 6

TRUSS CABLE SEMI-SUBMERSIBLE FLOATER FOR OFFSHORE WIND TURBINES AND CONSTRUCTION METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This present application claims the benefits of priority from the United States of America provisional application No. 61/407,730, entitled "TRUSS CABLE SEMI-SUBMERSIBLE FLOATER FOR OFFSHORE WIND TURBINES AND CONSTRUCTION METHODS", filed on Oct. 28, 2010.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

REFERENCES

[0003] (1) U.S. Pat. No. : 4,702,321, Filing date: Sep. 20, 1985, Issue date: Oct. 27, 1987

[0004] (2) U.S. Pat. No. : 6,263,824, Filing date: Dec. 23, 1997, Issue date: Jul. 24, 2001

[0005] (3) U.S. Pat. No. : 7,819,073, Filing date: Jun. 2, 2006, Issue date: Oct. 26, 2010

[0006] (4) U.S. Pat. No. : 7,612,462, Filing date: Apr. 24, 2008, Issue date: Nov. 3, 2009

FIELD OF INVENTION

[0007] Embodiments of present invention relate generally to the field of floating offshore wind turbines for offshore wind power generation. More particularly, embodiments of present invention relate to the field of a semi-submersible floater with a truss system for connecting the columns and a tensioned cable system for connecting the main structural components to improve structural strength and integrity, and associated methods for construction and installation. Furthermore, the invention also relates to the use of composite materials for the whole or part of the semi-submersible wind turbine floater construction.

BACKGROUND OF INVENTION

[0008] Conventionally, semi-submersible floaters used in deepwater offshore oil and gas exploration and production are built with columns and pontoons which are enclosed buoyant structures using steel material as shown in FIG. **1**. This kind of oil and gas steel structure and hull form are large and costly. The present invention aims to provide an innovative semi-submersible floater with unique configuration connected by truss and cables which enables a floating wind turbine to be constructed, towed vertically and installed offshore at significantly lower cost than a conventional semi-submersible floater.

SUMMARY OF INVENTION

[0009] Truss cable semi-submersible floater for offshore wind turbines and construction methods are provided to provide more cost and weight efficient floater with better stability and structural strength and dynamic performance for offshore wind turbines. Parts of the structure can be made of composite materials.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. **1** illustrates a prior art of a semi-submersible floater used in oil and gas production according to some embodiments of the present invention.

[0011] FIG. **2** illustrates a front view of a truss cable semi-submersible floater for a wind turbine according to some embodiments of the present invention.

[0012] FIG. **3** illustrates a front view of a tower sleeve with special contact pads according to some embodiments of the present invention.

[0013] FIG. **4** illustrates a front view of a tensioned cable system for a semi-submersible floater for a wind turbine according to some embodiments of the present invention.

[0014] FIG. **5** illustrates a perspective view of construction of a column with composite donut ring according to some embodiments of the present invention.

[0015] FIG. **6** illustrates a perspective view of a typical column and base steel and composite-concrete system according to some embodiments of the present invention.

DETAILED DESCRIPTION OF THE PREFFERED EMBODIMENT

[0016] With reference to FIG. **2**, a truss cable semi-submersible floater (hereinafter referred as "floater") includes a hull, a tower, and a tensioned cable system. The hull mainly includes 3 components: columns, including a center column **1***a* and outer columns **1***b*, trusses coupled to the columns, including an upper truss **2***a* and a lower truss **2***b*, and column bases coupled to the columns and the trusses, including a center base **3***a* and outer bases **3***b*. The hull can have multiple outer columns for stability, typically 3 columns (as shown in FIG. **2**), but also can have 4 columns or more. The hull has an in-service draft in the order of 60 ft to 80 ft depending on metocean conditions of the deployed area. The columns are most buoyant to provide the buoyancy for the wind turbine and rotor blades, which can be coupled with the floater and located above the water surface. The column bases, which can be tanks, provide stability for wet tow and hold ballast (sold or water ballast) for inplace conditions. The upper and lower trusses can be welded to the columns.

[0017] The tower **6** extends from the top of the center column **1***a* to the rotor for supporting the turbine and rotor blades. The tower **6** can be formed as a column structure. In some embodiment, as shown in FIG. **3**, a tower sleeve **4** can be used with the tower **6**. The tower sleeve **4** is a specially designed structure to allow the tower **6** to penetrate it without rigid connection. In some embodiment, the tower sleeve **4** is designed to contact the base of the tower **6** at certain points through specially designed contact pads to merely transmit forces without transmitting moments. This design feature will reduce the load into the upper truss **2***a* to give more efficient structural design.

[0018] With reference to FIG. **4**, the tensioned cable system can have multiple tensioned cables to connect the tower and the hull together to improve the dynamic performance of the floater structure. In some embodiments, the tensioned cable system includes lower tensioned cables **7***a* for connecting outer bases **3***b* at the bottom of the columns. In some embodiments, the tensioned cable system includes upper tensioned cables **7***b* for connecting the topside of the outer columns **1***b*. In some embodiments, the tensioned cable system includes diagonal tensioned cables **7***c* for diagonally connecting the mid lower tower **6** to the end of the upper truss **2***a*, which is at the top of the outer column **1***b*, to reduce the bending moment at the bottom of the tower **6**. The tensioned cables are preferably made of steel wire or similar materials.

[0019] In some embodiment, the floater can include a mooring line **5**. The hull with three outer columns **1***b* can have 3 mooring lines **5**, which can be pre-installed with drag anchor, suction anchor, or pile anchor for stabilizing the floater.

[0020] With reference to FIG. **5**, the columns can be made of hybrid materials, including steel and composite materials, for reducing cost and weight. The upper and lower columns **8***b* are preferably made of steel, and the middle column **8***a* is made of a series of composite donut rings, which are made of composite tubes filled with concrete inside. The upper and lower columns **8***b* can be connected to the middle column **8***a* by grouting. In some embodiments, a watertight composite membrane **8***c* can be glued to the inside of the composite donut ring or the outside of the composite donut ring, even throughout the entire column to ensure that the column is watertight.

[0021] With reference to FIG. **6**, a column includes a deck, a girder, and composite donut rings. The composite donut rings are placed on each other vertically to form a composite column section. The girder is substantially placed at 90 degrees inside the column. The deck is to be used to divide the column into two watertight compartments. Both the deck and the girder are preferably made of steel. A column base, as a column, also includes a deck, a girder and composite donut rings.

[0022] In some embodiments, a method of constructing a column with composite materials includes providing composite donut-shaped rings, placing multiple composite donut rings on each other vertically to form a composite section of a column, providing a steel section of the column and connecting it to the composite section of the column by grouting, attaching a watertight composite membrane to the inside or outside of the composite donut rings for connecting the composite donut rings and ensuring water tightness, placing a substantially vertical girder into the column, placing a deck into the column to divide the column into two watertight compartments. All or parts of the methods described above can be done on the land. Besides, a method of constructing a floater can further include installing a column base, a tensioned cable system, a tower, and a tower sleeve to the column, and coupling upper and lower trusses to the upper and lower ends of the columns. Then, the assembly of the columns can be loaded into water. The installation of turbine tower and assembly can be done in sequence in the water at quayside. Finally, the entire assembly of the floating system can be towed to the sea preferably at a draft within the depth of the column base, towered to in-service draft and fixed at the seabed with pre-set mooring lines.

What is claimed is,

1. A floating system comprising:
- a plurality of horizontal lower and upper truss system;
- a plurality of vertical buoyant columns, with one column at the center of the pattern, coupled with the truss system at the upper level;
- a plurality of large base tanks with diameters greater than the vertical buoyant columns, coupled with the truss system and the vertical columns, with one large base tank at the center of the pattern, at the lower level for ballast water or solid material;
- a wind turbine assembly supported by the column at the center of the pattern associated with the central large base tank at the lower level while horizontally constrained at the upper level by the truss system;
- a plurality of tensioned cable system of multiple tensioned cables to connect diagonally the wind turbine tower at the middle portion and the upper ends of the vertical buoyant columns together;
- a plurality of tensioned cable system of multiple tensioned cables to connect diagonally the upper and lower ends of the vertical buoyant columns;
- a plurality of mooring lines linking the floating system to the sea floor.

2. The floating system according to claim **1** wherein said entire assembly can be constructed using conventional steel and composite materials according to a method comprising;
- donut shape rings and tubes made of composite material first to form one column ring;
- the donut rings are placed on top of each other and filled with concrete to each tube;
- a watertight composite membrane is glued to the donut rings either from inside or outside or both to ensure the water tightness of the column and connecting each of the composite rings;
- the composite column section is coupled with the upper and lower sections of the column by grouting;
- the upper and lower sections of the column are made of conventional steel;
- the upper and lower trusses are welded to the column upper and lower sections;
- the assembly of the floating system is carried out on land;
- the completed floating system is loaded out into the water at quay;
- the wind turbine tower and assembly is installed on the floating system at quad side;
- the floating system is towed to sea at a installation tow draft within the depth of the large base tanks;
- the floating system is connected to the pre-set mooring lines at sea;
- the floating system is lowered to the in-service draft by water ballasting.

3. The floating system according to claim **1** wherein said entire assembly having a sleeve system for the wind turbine tower comprising,
- a tower sleeve associated with the center column at the upper level connected by the truss system to the outer columns;
- the tower sleeve is to allow the tower to penetrate it without rigid connection;
- the tower sleeve is to have contact pads to contact the tower at certain points;

4. The floating system according to claim **1** wherein said entire assembly having a truss system comprising horizontal truss space frame members at the lower and upper levels;

5. The truss system according to claim **4** wherein said truss space frame members can be made of light-weight composite material;

6. The floating system according to claim **1** wherein said entire assembly having a tensioned cable system comprising diagonal tensioned cables;

7. The floating system according to claim **1** wherein said entire assembly having a vertical buoyant column at the center of the pattern;

8. The floating system according to claim **1** wherein said entire assembly having a plurality of base tanks with diameter greater than the vertical buoyant columns;

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