

UNFLOP-Unsinkable-Stable Unaffected by Waves Floating Truss Platforms

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ABSTRACT

There is endless-sustainable-clean Marine Renewable Energy (MRE) in open seas-oceans from Wind, Waves, Undersea or Tidal Currents and Solar PV. Respective under development or mature technology Marine Renewable Energy Converters (MREC) to harvest-convert MRE to electricity need a “base” to operate and Electricity Substations and Transmission System (ESTS) to combine all outputs into one for transmission to Shore. In shallow waters ca. 40-50m, “base” can be the seabed, otherwise “floating base” is necessary or individual floating MREC with own ESTS-very expensive solution, unless many are grouped and use a common ESTS. But, for truly cost-effective AND Grid-Friendly electricity transmission to shore, many-many MREC of ALL different MRE must be grouped on ONE “floating base”.

The *PROBLEM* with existing floating structures is *the large volume units and large water-tight compartments*. From the hull-type boats-ships (Titanic, Exxon Valdez...), to special floaters like “column stabilized semi-submersibles” (Deepwater Horizon, Alexander Kielland...) ALL share two very bad “habits”, they are rocked by waves (sometimes out-of-limits) and sink when large watertight compartments are damaged and flooded.

The “Unsinkable-Stable Unaffected by Waves Floating Truss Platform” technology, with individually buoyant water-tight or solid truss-members of hydrodynamic shapes, is *THE SOLUTION* for this and MANY other problems-needs for marine applications.

Keywords

Unsinkable, Unaffected by Waves, Floating Platforms, Breakwater, Buoyant

1. INTRODUCTION – THE PROBLEM

Existing technologies for floating structures to support Offshore floating Wind Turbines or for Oil & Gas Rigs are based on the concepts of one *LARGE VOLUME (LV)* semi-submerged floating leg-column like the Spar Buoy, or a small number of 3-6 semi-submerged floating *LV* legs-columns like the Tension Leg Platforms-TLPs and Tripod Barges, and the “Column-Stabilized Semi-Submersibles” like the Deepwater Horizon Oil Rig-drilling platform with 4 *LV* legs, which created such HUGE DISASTER to nature and people in the Gulf of Mexico, and the Alexander L. Kielland Oil Rig with 5 *LV* legs that was used as a floating hotel and took 123 lives down with it. Deepwater Horizon sank because 2 of its 4 legs were destroyed by the fire (ONE would have been enough!). In fact, in the second day, the instructions to the fire-fighting vessels from Control Room were to direct-throw the water *LOW to the legs to protect them*, instead of on the flames on the top of the platform. The first paragraph of Paper Nr. 4236-MS, titled “Investigation of the Alexander L. Kielland Failure-Metallurgical and Fracture Analysis” [1] in the Offshore Technology Conference, 3-6 May 1982, Houston, Texas, states: “At about 6.30 p.m., on March 27, 1980, one of the five legs of the hotel platform *Alexander L Kielland* separated from the rest of the structure in a storm on the Ekofisk field in the North Sea. Approximately 20 minutes later the platform capsized, resulting in a loss of 123 lives; 89 persons were rescued. The failure started with the fatigue fracture of one of the lower tubular bracings... combined with poor welding and high residual stresses...”

These two cases are not the only examples. There are plenty more such disastrous incidents with this type of floaters depending on a few “legs” for their floatability. These types of floating structures are not unsinkable or unaffected from waves (due to the *LV* units-legs), and must be abandoned by personnel when weather is

forecasted to exceed their endurance-safety limits, reducing their operationality time. We have to conclude that the bottom line on these floating structure concepts is that, if just ONE of their very few **LV** legs-columns loses its buoyancy, it is unavoidable that the structure capsizes and sinks.

In a similar way, the hull-type boats-ships are known to be very affected from waves, many times beyond their endurance limits, and capsize and sink when large watertight compartments are damaged and flooded, resulting most of the times in HUGE DISASTERS to nature or people or both, and the examples are endless.

2. GENERAL DESCRIPTION OF UNFLOP

UNFLOP (GR Pat. Pending, O.B.I. appl. nr. 20130100211-10/4/2013) is based on truss structures that comprise individually buoyant, hollow water-tight or solid truss members of various hydrodynamic shapes, which are interconnected through fixed or articulated jointing systems, either of which facilitate fast and easy assembly-disassembly of individual members without disturbing near-by members or the truss system, even inside the water. The targets of the innovative UNFLOP technology are to enable design-construction of semi-submerged (UNFLOP-Surface) or fully-submerged (UNFLOP-Sub) floating structures, for any conventional or special application, either in the sector of shipping (UNFLOP-Ship) or any other sector for floating structures to support any kind of installations, which will be completely FREE from these two “bad habits” of existing technologies, i.e. being affected from waves and being sinkable, and additionally, to create some other betterments-advantages in relation to existing state of the art, and especially the capability of servicing or repairing incidental damages to floating structures, immediately, at the operating location at sea, and the reduction of energy consumption and enabling “all weather” travelling/sailing for certain types of UNFLOP-Ships/Boats in the shipping sector.

Any UNFLOP is practically *truly unsinkable* because the majority of its truss members cannot be flooded and lose their buoyancy as they are solid bodies made from composite materials with lower specific weight than water as needed, and in any case, a very large number of individually buoyant truss-members must lose their buoyancy *at the same time* for UNFLOP to be in danger of sinking, which is something extremely difficult to happen either by chance or on purpose! If needed, a number of truss- members can have the form of hollow water-tight compartment to be used as buoyancy controllers with variable ballast, but this has no effect on the “*truly unsinkable*” trait of the UNFLOP structure.

Any UNFLOP-Surface or UNFLOP-Ship is practically *truly stable-unaffected by waves* because waves slide-by the hydro-dynamically shaped truss members and the forces exerted by thrust or buoyancy change effects on individual or small groups of adjacent truss-members are minor and fast and mostly cancel each-other-out over the total structure area, *without influencing the overall system INERTIA*.

UNFLOP can extend to any size area-height and to more than one levels of continuous truss sections for its total area or at specific truss system locations, increasing *FUNCTIONALITY, INERTIA* and *BUOYANCY*, as needed.

Breakwater function is *INHERENT* to any UNFLOP-Surface design-structure, and its wave energy absorbing capabilities depend on the *WIDTH OF THE STRUCTURE in the direction of the wave propagation*. These capabilities can be increased as needed when any kind of Wave Energy Converters (WEC) or Wave Energy Absorption Grids (WEAG) are incorporated in the design. This function is possible *ONLY* because any suitable area UNFLOP-Surface is *STABLE, does not move in relation to the Still Water Level (SWL) on the vertical axis*.

Suitable multiple catenary anchoring or GPS Dynamic Positioning System (GDPS) can be used to stabilize any UNFLOP-Surface to its operating location. For small size-area UNFLOP-Surface systems with low *INERTIA* related to the expected wave level, Intense Flotation methods-Taut Lines Platform technology (TLP) may need to be considered. Also Intense Flotation methods-TLP will be necessary in most UNFLOP-Sub applications.

3. THE BASIC RANGE OF UNFLOP COMPONENTS

3.1. Truss-members

The hollow water-tight or solid truss members of any UNFLOP designed to operate at a fixed location are normally of cylindrical shape (**C**) and they form pyramid and / or orthogonal form basic truss elements. Alternatively, when UNFLOP is designed to be either in a fixed location inside moving water (tidal current-

river), or in motion in the water through tugging or as a self-propelled type of “boat” (UNFLOP-Ship), they have hydro-dynamic hydrofoil (**Fv**, **Fh**, **Fa**) or torpedo (**T**) shapes with suitable orientation in the truss system and form mostly orthogonal and/or triangular basic truss elements. Indicative truss member shapes are shown in Figures 1, 2, 3 and 4 below:



Figure 1: Member C



Figure 2: Member T

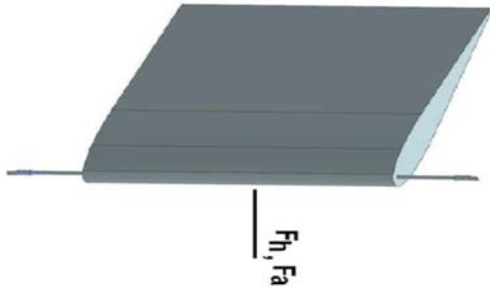


Figure 3: Member Fh-Fa

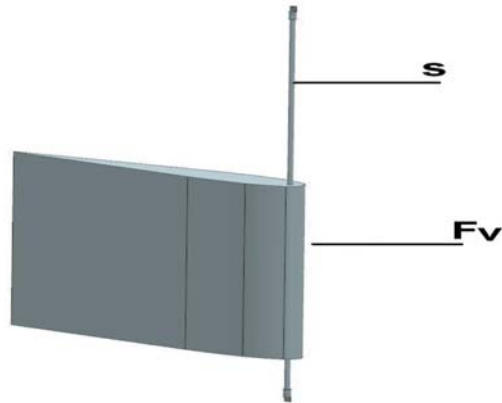


Figure 4: Member Fv

3.1.1. Unsinkable-solid truss-members

The majority or all fully-submerged and semi-submerged truss members in any UNFLOP truss system cannot be flooded and lose their buoyancy as they basically are solid bodies made from composite materials with lower specific weight than water as needed. The unsinkable member comprises a *Strength Element* (**S**) of “small” volume, not necessarily buoyant, that secures the geometry and strength of the truss, which is “encased by” and supports the “large” volume material with lower specific weight than water that makes the member buoyant.

To minimize wave effects on the truss system when the inherent Breakwater function is not needed or when the wave energy should be absorbed by WEC, the semi-submerged members extend with their “large” volume body-material only marginally above the Still Water Level (SWL) under full operating load-maximum draft, and the truss structure above water is completed to the necessary height only with the **S** part of the members. Similarly, all the top part of the truss structure constantly out of water and above the maximum expected wave height comprises only bare *Strength Element-members* (**D**). Alternatively, this top part of the truss can also comprise individually buoyant members as a “*last resort/back-up safety buoyancy*”. Depending on the design, **D** members may be used in any part of the truss to secure the strength and geometry of the structure and proper operation of the fixed or articulated jointing systems. (For **S** and **D** see Figures 7, 8, 9)

3.1.2. Hollow water-tight truss-members with adjustable buoyancy

Depending on the application, some truss members could be hollow water-tight bodies with adjustable buoyancy through adjustable ballast. In this case it is possible such a member to lose its buoyancy for any reason even malfunction of the ballast adjustment and maybe influence negatively the overall system buoyancy. In any case this cannot create any danger of sinking because these members are used to create maximum draft when fully “flooded” and under full operating load of the complete truss structure.

3.2. Jointing systems for truss-members

Indicative design of Joints for interconnection of the truss members through fixed and/or articulated jointing systems are shown in Figures 5 and 6 below:

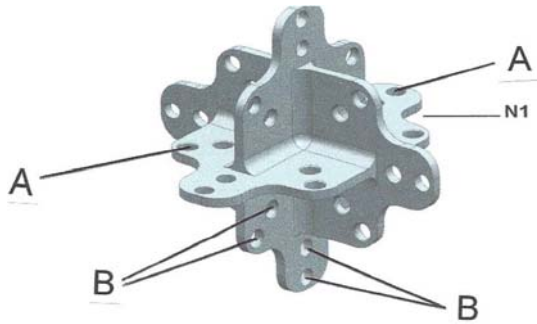


Figure 5: Joint N1

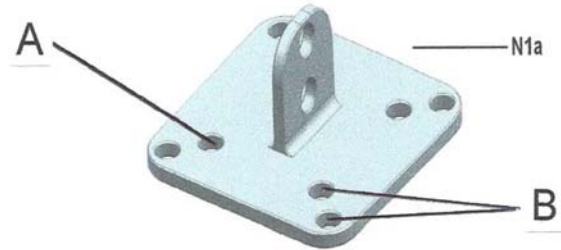


Figure 6: Joint N1a

Joints **N1** and **N1a** facilitate both jointing methods in any one truss system. Articulated connection is when only one pin is used to connect the truss member end to one of the holes in the joint (**A**) and results to elimination of torques and only axial forces developing on the member between its two ends if they are both articulated. Fixed connection is when two bolts are used instead (**B**). The best choice for **A** and/or **B** connections depends on the specific truss system design. In any case, both connections facilitate fast and easy assembly-disassembly of truss members. Any forms-shapes of basic truss elements can be secured with either jointing method or any suitable combinations.

4. THE BASIC RANGE OF UNFLOP TRUSS STRUCTURES

4.1. Pyramid-only basic truss elements

This design is generally suited as UNFLOP-Surface to support any kind of floating installations, and especially as “Marine Renewable Energy Sources Integrated Applications Platform” (MARESINAP) to support any kind and number of MREC. Similarly, as UNFLOP-Sub it can support any kind of installations, and especially Tidal or Underwater Current Converters (TUCC) at the desired depth, in combination with a “mother” MARESINAP.

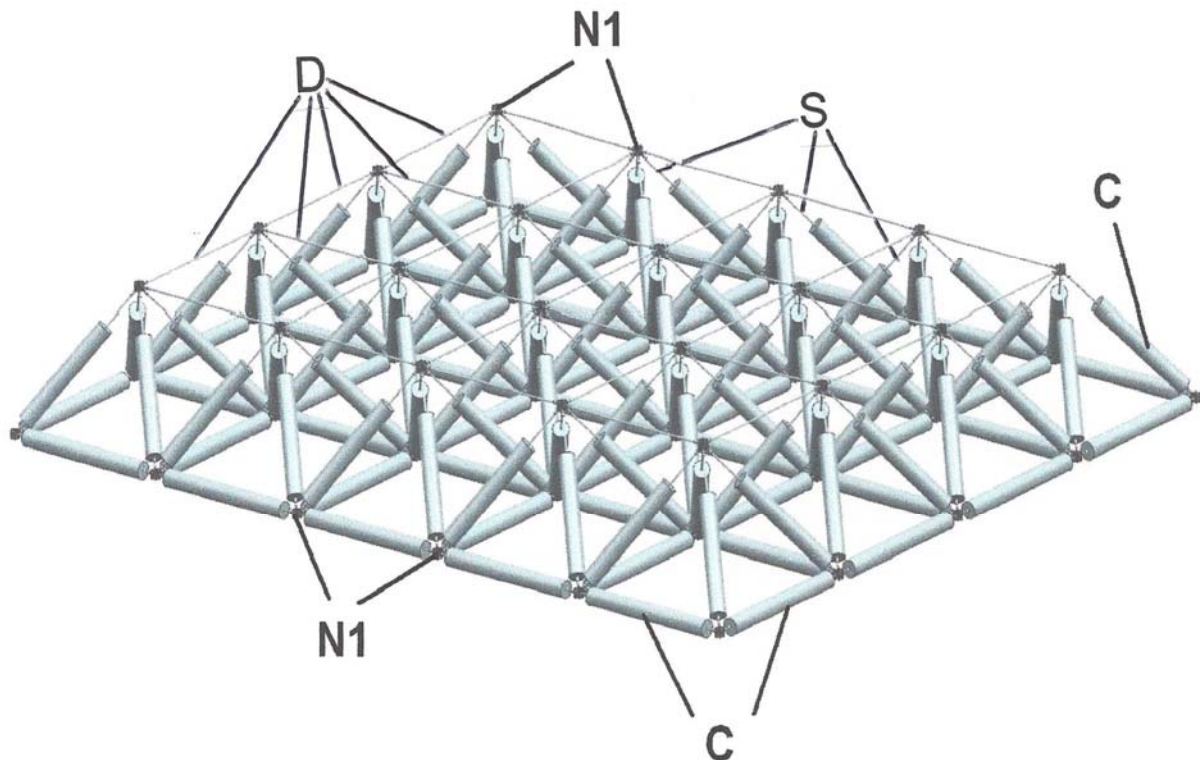


Figure 7: UNFLOP with pyramid-only basic truss elements

4.2. Pyramid and orthogonal basic truss elements

The UNFLOP-Surface design shown below comprises both pyramid and orthogonal basic truss elements, with vertical semi-submerged cylindrical truss members (CV) and fully-submerged horizontal cylindrical truss members added to the pyramid-only structure, to increase floatability and load capability.

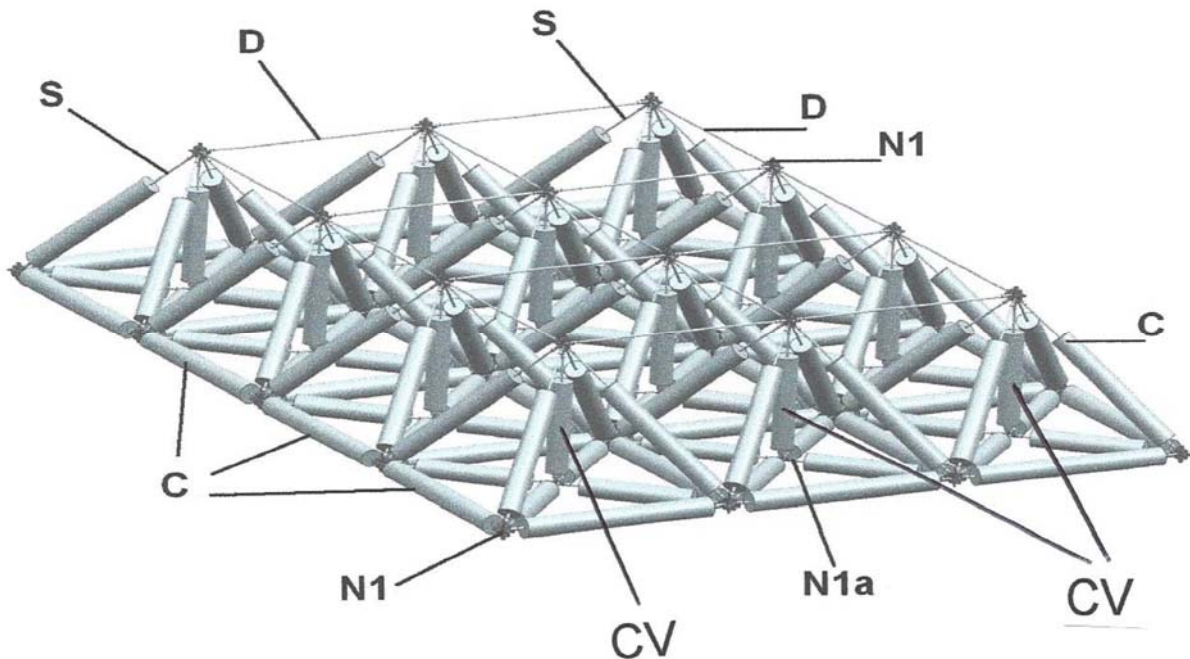


Figure 8: UNFLOP with pyramid and orthogonal basic truss elements

4.3. Orthogonal-only basic truss elements

The UNFLOP-Surface design shown below comprises orthogonal-only basic truss elements, and is intended for simple-low cost applications, like floating pedestrian piers or recreation platforms in protected-low wave areas.

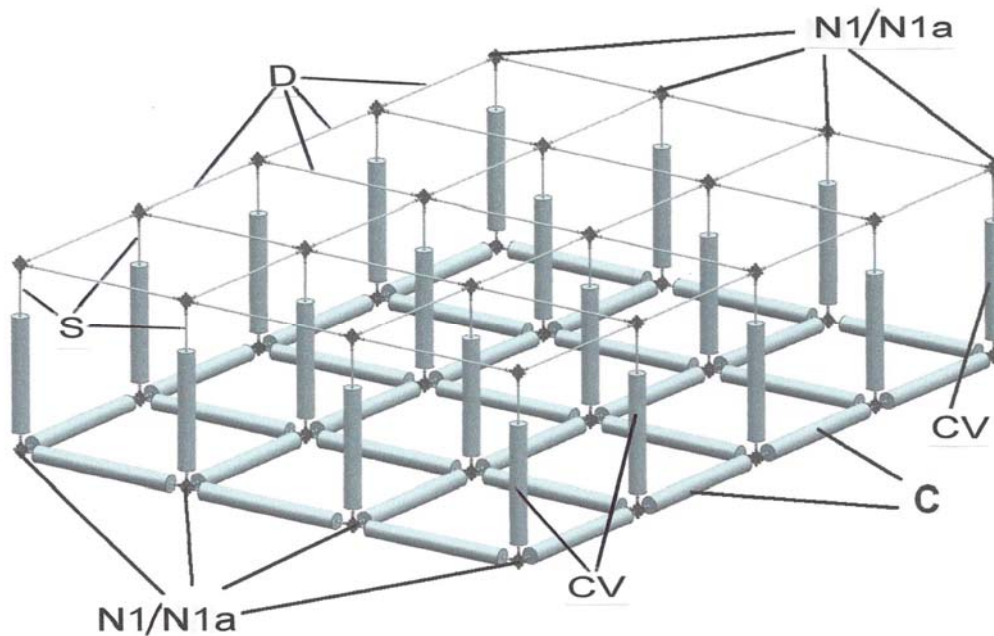


Figure 9: UNFLOP with orthogonal-only basic truss elements

4.4. Hydro-dynamic, hydrofoil/torpedo shape basic truss members

The UNFLOP design below comprises hydrofoil and torpedo shape members forming orthogonal and triangular basic truss elements, and can be either in a fixed location inside moving water or in motion in the water through

tugging or as a self-propelled UNFLOP-Ship. Hydrofoil members can be in horizontal-**Fh**, vertical-**Fv** or at some angle-**Fa** position and not necessarily of the same size/shape, and torpedo members-**T** in horizontal.

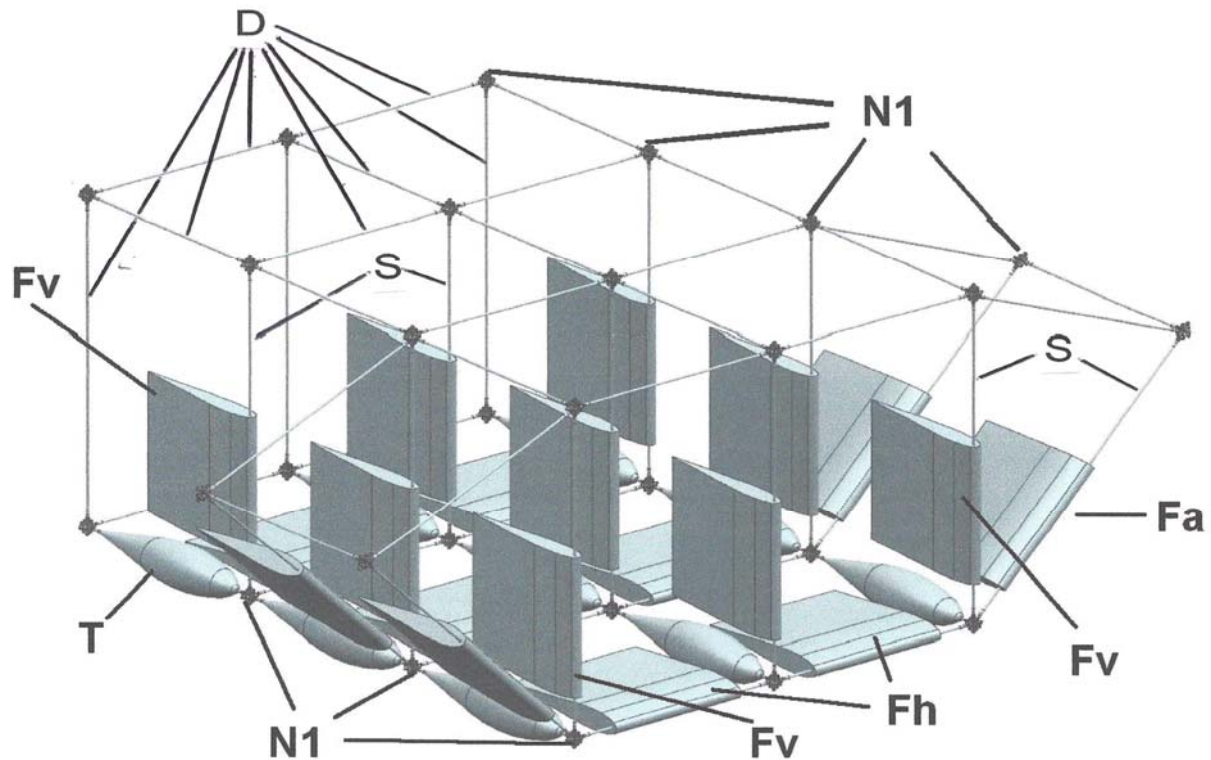


Figure 10: UNFLOP with hydro-dynamic, hydrofoil/torpedo shape members

In UNFLOP-Ship applications, any necessary number of **Fv** can be used as rudders and **Fh** and **Fa** can be used through suitable sensors and servo-drive mechanisms for stabilization of motion and the tilt caused by turning or side wind thrust on the top-above water structure (not shown). The main body of the overall ship/boat structure that contains the payload is mounted on the top of the truss structure and can have “hull” type shape that can provide a “*last resort/back-up safety buoyancy*”, if many of the individually buoyant truss members are damaged-loose floatability. The **Fv** semi-submerged members extend with their “large” volume body-material only marginally above the SWL under full operating load-maximum draft, and their **S** part extends as necessary so that the “hull” is constantly above the maximum expected wave height and the wave effects are minimal. Alternatively, the **S** parts can be designed with the capability to be withdrawn simultaneously into the “hull” and the opposite, to lower or raise the “hull” from the SWL, as it may be necessary or useful for the sailing in high waves or in calm waters and for harbouring. Also some members could be of the hollow water-tight type with adjustable buoyancy through adjustable ballast, to control the draft in relation to the payload.

Depending on the width/height of the top “hull” structure and the centre of gravity of the overall structure, the truss structure providing the floatability can be wider than the top “hull” structure for better stability. Another design option is that the width of the truss structure can be adjustable from a minimum as the top “hull” to the necessary maximum, by moving simultaneously outwards all the end side members (**Fv**, **Fh**, **Fa**, **T**) on both sides to the desired width through suitable mechanisms. The minimum width will be used when coming in or going out from harbouring, and the maximum when sailing in open seas.

The UNFLOP-Ship technology provides the following advantages over existing state of the art:

- 1) Almost complete absence of wave effects-influence, which means capability for safe sailing in much worse sea conditions without any disturbance-dangers for passengers and load, i.e. *ALL weather sailing*.
- 2) Significant reduction of sinking possibilities from collisions or heavy wave conditions
- 3) Significant reduction of water resistance-drag to the motion, which means reduction of fuel consumption
- 4) Capability for servicing or repairing incidental damages immediately, at the operating location at sea, by replacing the damaged members/components.

5. INDUSTRIAL DESIGN/MANUFACTURING CONSIDERATIONS AND BENEFITS

In all semi-submerged UNFLOP truss structures it is necessary to take into consideration from the start the necessary maximum-minimum draft in relation to the expected maximum-minimum overall structure weight and payload, and the difference of the draft limits will define the size-volume of the semi submerged truss members. If it is necessary to reduce this draft difference, a suitable number of hollow water-tight members with adjustable buoyancy must be included, while *the largest part of the necessary overall system buoyancy* can be provided by the fully-submerged members that can have larger volumes than the semi-submerged ones.

For all kinds of UNFLOP applications, the choice of materials for the overall structure is of prime importance. In the existing state of the art, use of *HEAVY STEEL* is predominant for most floating structures, to generate the displacement of the *LARGE* water volume/weight needed for stabilized flotation, also in relation to the *LARGE INERTIA* needed to combat related *LARGE* wave effects on their *LV* floating compartments. Large water volume displacement and large inertia are not necessarily needed by UNFLOP structures for those purposes, and light-weight but very strong composite materials must be used. Especially for UNFLOP-Ship applications, light-weight strong materials must also be used for the top structures intended to accommodate the various payloads.

The open options for high level modularity of the UNFLOP parts/components provide many advantages in the manufacturing processes, in logistics for transporting parts to assembly locations and in the final assembly. The *MODULAR* nature of any UNFLOP structures makes it possible for the individual parts and accessories to be manufactured at any convenient locations with mass production industrial methods and be transported-shipped with low cost logistics to any convenient sea-side locations, to be assembled in any convenient size *MODULAR SECTIONS*, which can be easily launched in the water and be assembled-interconnected between them while afloat to the final UNFLOP size with easy methods, or be tugged in convenient size *MODULES-SECTIONS* and assembled at the final operating location to the final UNFLOP size.

6. FULLY ENGINEERED EXPERIMENTAL SCALE MODEL

A small size 4,20x4,20m, 5x5 pyramid scale model has been designed for wave-tank testing. The joints **N1** and **N1a** have been produced by CNC machining from aluminium and the cylindrical truss members from plastic and aluminium. A small 5x2 pyramid section of this model has been “tested” successfully in a swimming pool:

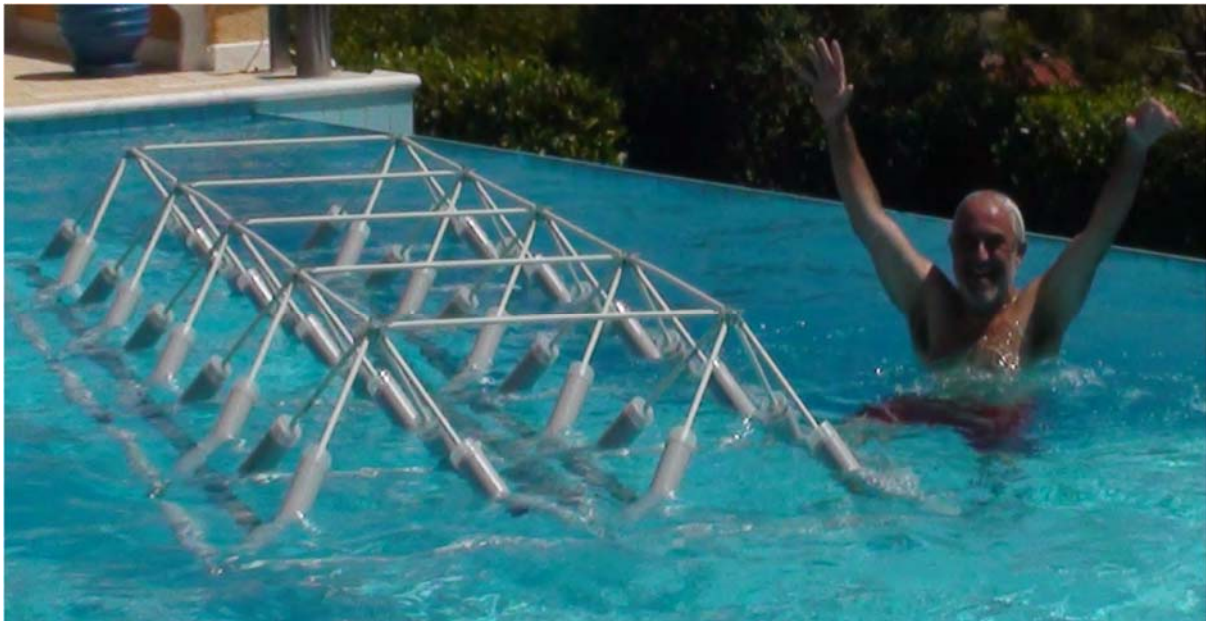


Figure 11: Testing of UNFLOP scale model. View video at: <http://www.youtube.com/watch?v=B4JepSCnXy4>

7. COMPUTATIONAL FLUID DYNAMICS-CFD ANALYSIS-SIMULATIONS

The initial CFD-Computational Fluid Dynamics analysis-simulations performed with pyramid UNFLOP models prove that they are truly stable-unaffected from waves. Moreover, these simulations have shown that the *BREAKWATER function is INHERENT* to this pyramid-only UNFLOP design. This is a remarkable finding that

suggests UNFLOP in general can protect coastlines from wave surges, even up to tsunami scales given the necessary further R&D, *IN ADDITION* to any other functions-applications that may be covered on any location. View CFD simulation videos with UNFLOP model 10x10 pyramids, 10m side, 100x100m area:

Test 1 <http://youtu.be/twl-jYsTdwk> wave height 4m, period 5sec-wavelength ~ 35m

Test 2 <http://youtu.be/P1wa-palGMM> wave height 5m, period 5sec-wavelength ~ 50m

Test 3 <http://youtu.be/P0Z7yUo6gXA> wave height 5m, period 10sec-wavelength ~ 100m-extreme limiting case

Related graphs are shown below:

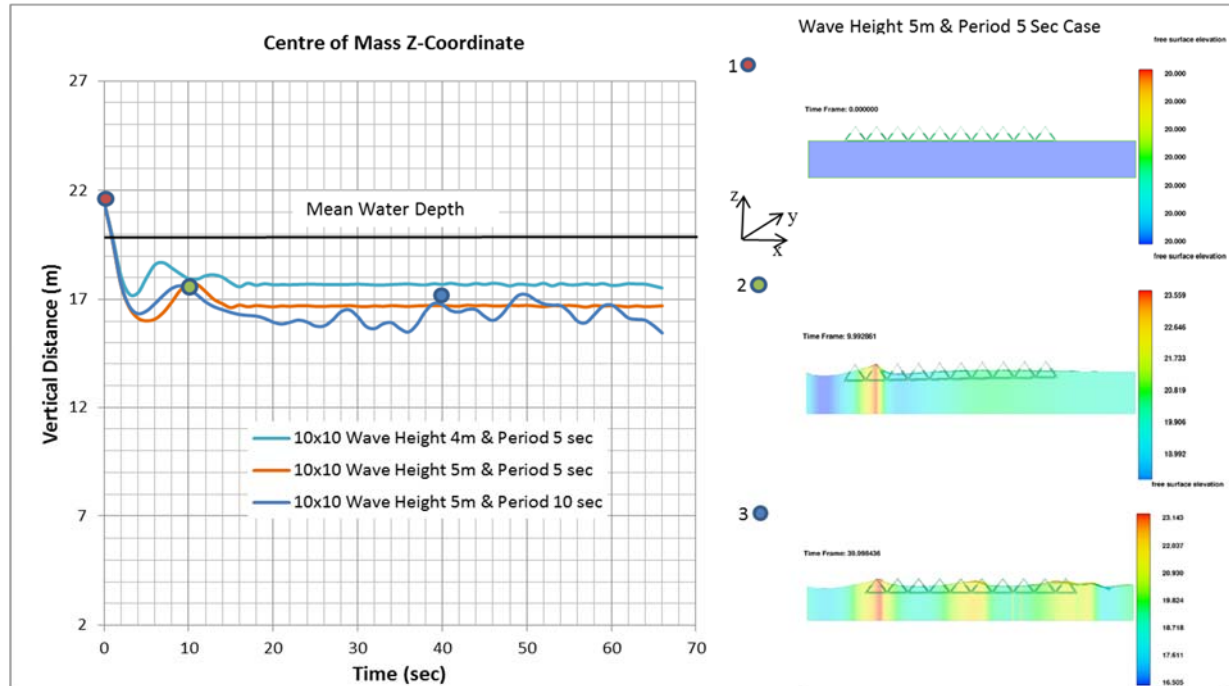


Figure 12: CFD simulation related graphs for Tests 1, 2, 3

These CFD simulations show that the pyramid-only UNFLOP structure remains stable-unaffected by waves when their wavelength is smaller-not comparable to the width of the platform in the direction of its propagation.

8. THE BREAKWATER FUNCTION

Other than the inherent capabilities the UNFLOP Breakwater function can be increased by adding Wave Energy Absorption Grids-WEAG (G1, G2..) that break-up the cohesiveness of waves causing dispersion of the water. This function is enabled only because UNFLOP remains stable related to the SWL also with the Grids-on, since thrust effects from the up-down wave motion are small and fast and at random directions and again cancel each other out without effect to the system INERTIA. This should also be valid even if a Tsunami passes through, as long as the UNFLOP inertia is large enough not to be influenced by the fast-transient tsunami effects and the platform width is at least double the expected wavelength, as indicated in the CFD simulations.

In general, for effective wave surge absorption, the UNFLOP structure must be located-operating at suitable depth-shallows that will result to a “manageable” combination of wavelength and wave height. In the special case of Tsunami this may not usually be possible and a lot more R&D is needed for reasonably safe conclusions.

9. MARESINAP APPLICATION

Along with the **WWT** (Wing-Wheel-Turbines) and **PWT** (Puddle-Wheel-Turbines) new technologies (GR Pat. Pending, O.B.I. application number 20130100235-18/4/2013), MARESINAP can provide a TOTAL solution for harvesting MRE. **WWT**-Wind Generators and **PWT**-Hydro Generators (River/Wave/Tidal/Current) comprise two or more Frames-FR (Wings/Paddles) on common Shaft, which have one or more Airfoils/Hydrofoils (Foils) on their own Axles fixed parallel to the Shaft, that are free to change position between two terminals, utilizing the apparent fluid flow each experiences every moment, to absorb kinetic energy from their fluid, exploiting alternatively BOTH Drag AND Lift forces, irrespective of flow directions or turbulent form.

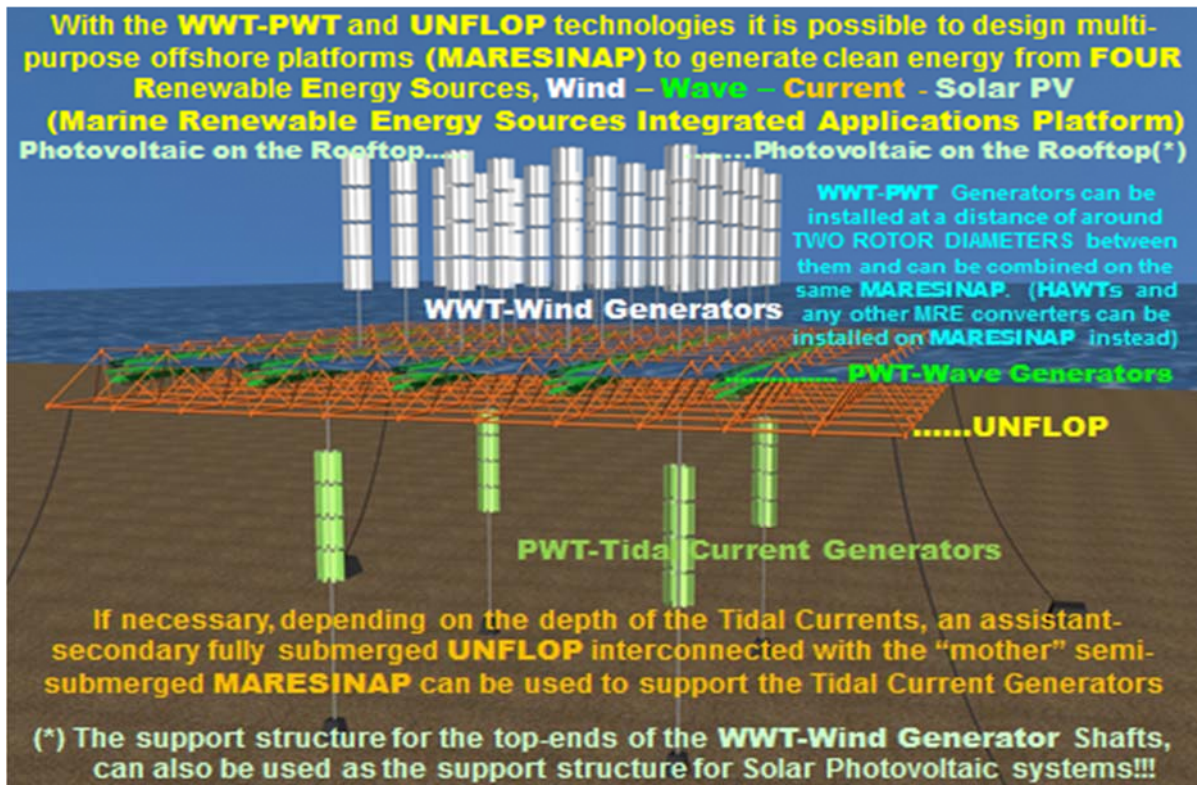


Figure 13: The MARESINAP concept

The **PWT** or other technology Wave Converters incorporated on **MARESINAP** increase the **BREAKWATER** capabilities of the system while transforming the wave energy to electricity

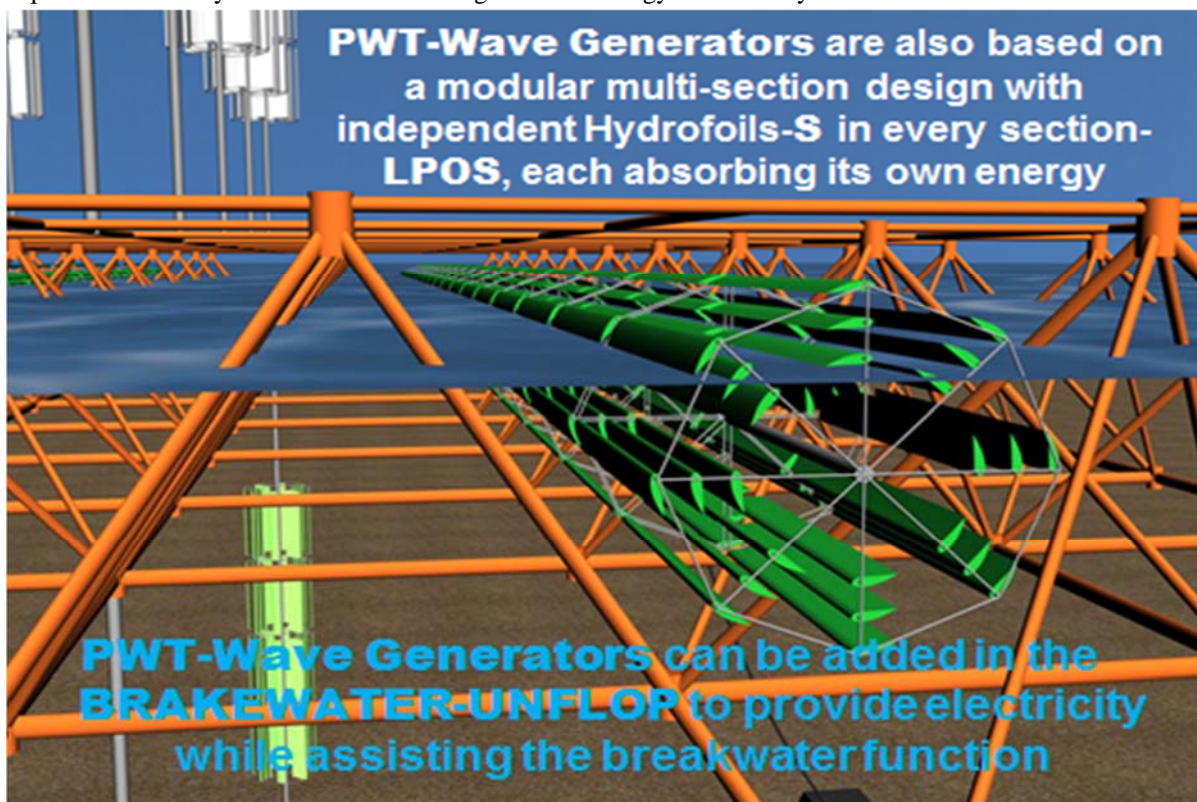


Figure 14: The **PWT** Wave Converter supported on MARESINAP

Any other MREC technologies, like the Spar Buoy floating HAWT (Horizontal Axis Wind Turbines) and OWC (Oscillating Wave Column) Wave Converters can also be supported-incorporated on MARESINAP. When

many-many different MREC for all available MRE from Wind, Waves, Undersea or Tidal Currents and Solar PV are grouped on a common MARESINAP and use common ESTS (Electricity Substations and Transmission System), the necessary truly cost-effective AND Grid-Friendly electricity transmission to shore is possible.

In conjunction to MRE harvesting, MARESINAP can also support any *desalination systems* and use part of the clean electricity produced “onboard” for their sustainable operation. Alternatively, if it is a better option, the desalination systems-facilities can be installed onshore and use the clean-low cost electricity there.

10. CONCLUSIONS, OTHER APPLICATIONS

Other than in MRE and BREAKWATER sectors, UNFLOP can find many applications in many Commercial, Industrial, Military sectors, like Tourism, Shipping, Air Transport, Manufacturing, “Poly-Aquaculture”, Urban development-Housing, as a safe and stable “*floating REAL ESTATE*” or “*Floating SEABED at the desired depth*”, a secure sub-structure for any kind of installations. In all cases UNFLOP-Surface will also naturally-inherently function as BREAKWATER to protect the nearby coastlines and / or Harbours facilities.

Especially for fish-farming, UNFLOP enables operation in any open waters and the implementation of the superior “Poly-Aquaculture” instead of “aquaculture” and the incorporation of all necessary installations for vertical production-overall procedures, as well as Wind and Hydro/Wave turbines-generators and solar PV systems, for total energy independence from Renewable Energy Sources. Conversely, “Poly-Aquaculture” can be incorporated within any MARESINAP system with the related benefits, and/or in parallel with any other application of UNFLOP.

In general and most important, various different functions can be incorporated together in the same UNFLOP system to maximize the benefits in every installation as may be needed. More possible applications are:

- 1) Floating hotels-apartments including mooring and heliport facilities for the tourism industry or just housing facilities (including MREC, Poly-Aquaculture...).
- 2) Floating substructures for any industrial, commercial, military installations (including.....)
- 3) Floating docks or harboring facilities in overcrowded tourist or commercial ports or open waters (including...)
- 4) Floating Warehouses and Airfields to facilitate ocean and air transport (including.....)

The specific MARESINAP, BREAKWATER and DESALINATION applications can certainly play a most SIGNIFICANT role in any Adapt To Climate strategies and planning anywhere in the world!!

References:

- [1] “Investigation of the Alexander L. Kielland Failure-Metallurgical and Fracture Analysis” Offshore Technology Conference, 3-6 May 1982, Houston, Texas