Y-Wind Semi

Most Affordable Floating Wind Solution for Horizontal or Vertical Axis Wind Turbine

Innovative and Robust Design

by VL Offshore

With Full Extension of Offshore Engineering and Design Experiences

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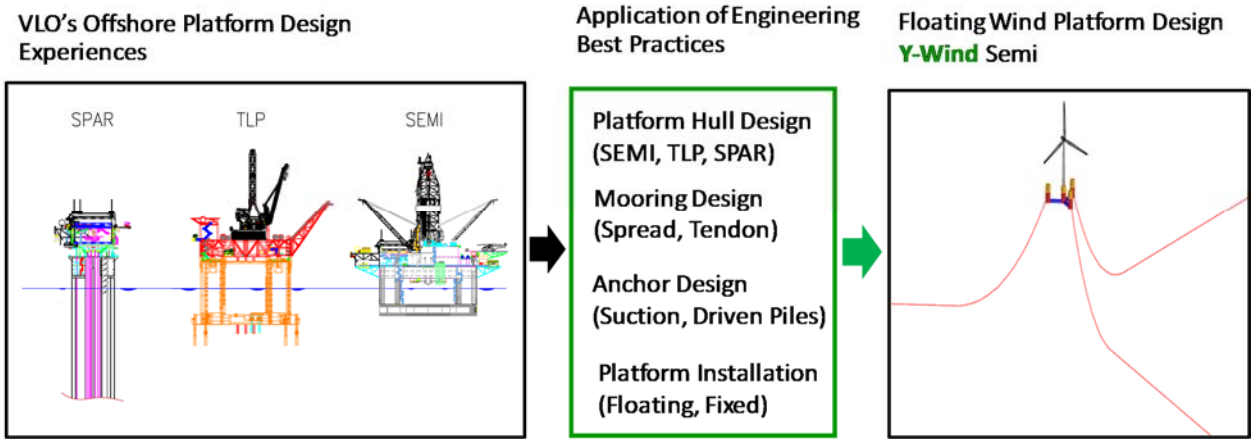
Y-Wind Semi Designed by VL Offshore

The Y-Wind Semi platform (foundation) is the most technically robust, cost-effective and adaptable floating foundation for offshore wind. Y-Wind is the result of extensive offshore engineering expertise and thorough life cycle cost analysis of the critical engineering challenges and key cost drivers of floating wind. The Y-Wind platform is designed by VL Offshore (VLO) incorporating and expanding their extensive engineering and design expertise established over the decades from various offshore projects in Semi-submersible, TLP and Spar platforms. VLO's team consists of key discipline engineers for the floating wind in naval architecture, structure, mooring and anchor, marine system, power cable and installation.

The Y-Wind design resolves key technical challenges and minimizes costs from the concept design all the way up to decommissioning including engineering, hull fabrication, tower integration, platform transport and O&M. The result is a platform that facilitates turbine performance to maximize revenue and that has low CAPEX and OPEX over the life of the platform. The platform can be utilized to support a range of turbine sizes from 2MW to 10+MW and of either Horizontal Axis Wind Turbine (HAWT) or Vertical Axis Wind Turbine (VAWT) configurations.

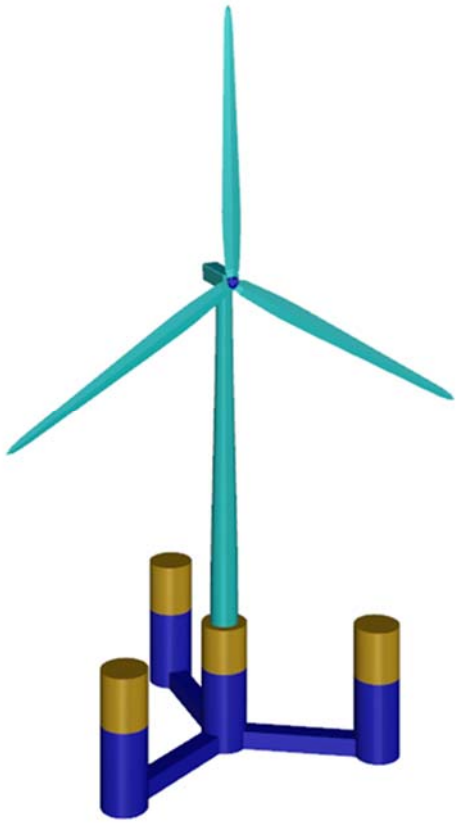


Innovative Design for Improved Platform Performances and Low Cost

Y-Wind semi platform comprises one center column to support the wind turbine, three outboard columns and pontoons connecting the center and outer columns which forms an "Y"-shaped hull. No bracings and deck structures are configured, which removes the potential slamming or airgap that can increase structural stresses. The platform dimensions are optimized to fit a wide range of approved fabrication yards and to minimize every associated cost from fabrication to installation and O&M. With one of the lowest steel weight to turbine power ratios, fabrication costs are the lowest possible. With its characteristic shallow draft, quayside access is available for tower integration and maintenance at more ports, harbors and fabrication yards worldwide than competing foundation designs. Y-Wind's shallow draft hydrostatic characteristics ensures stability during quayside tower integration, transit to installation, mooring connection and quayside access for maintenance. Furthermore, Y-Winds hydrostatic and hydrodynamic features results in low mean inclination angle during power production and reduced motions which improve the turbine performances without the need for using any expensive and complex active ballasting system.

Innovative Motion Attenuating Structures (MAS) are attached to the foundation which reduce platform responses significantly, but without increasing platform overall length (or width). Y-Wind foundation can be configured with various MAS shapes and arrangements to improve and tune the platform's hydrodynamic performance according to site specific criteria.

Design Strategies



The general industry trend is to use bigger turbines offshore to produce more power and lower the cost per MW installed. However, a bigger turbine requires a larger floating foundation to support the turbine weight and aerodynamic loads. The large platform has some economy of scale advantages but also has several disadvantages in constructability of the platform, especially by limiting fabrication yard selection by requiring larger fabrication capacity and deeper water depth at quayside to integrate the tower and turbine. All these disadvantages increase the life-cycle cost of the very large floating wind platform. The Y-Wind foundation is designed to be cost effective across a wide range of turbine sizes and from the first unit onwards.

VLO Engineers considered every critical cost driver associated with the performance, constructability, shipyard water depth and capacity, and execution to develop Y-Wind to be as cost-effective as possible. Factors considered include:

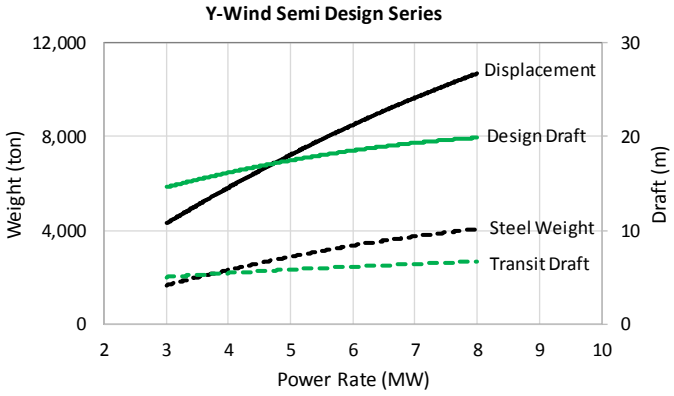
- Proper platform size to fit for local shipyard which improves the constructability
- Ease of fabrication of platform for constructability
- Shallow lightship draft to meet fabrication yard (or port) water depth
- No requirement of dedicated expensive vessel for wet-tow and installation
- Sufficient self-buoyancy to give stability during tow and installation, including for return to quayside for maintenance
- Low mean heel angle of platform during power production to improve the power production
- Passive ballasting operation to negate the need for expensive active ballasting systems on the foundation

Improved Hydrodynamic Technology

The Y-Wind semi platform can be configured without MAS or with several options of MAS: from narrow to wide, with porosity, or edge shaping to tune the platform responses depending on site metocean conditions. The MAS significantly reduce the responses of the platform dynamic motions, mooring loads and accelerations at turbine nacelle. The improved platform responses ensure maximum power output and increase turbine reliability, thereby increasing revenue and reducing O&M costs.

Scalability

Y-Wind platform can be readily scaled to accommodate various turbines from small to large power turbines. Sample series of the Y-Wind Semi designs for 3 MW, 5 MW, 6 MW and 8 MW horizontal axis wind turbines have been evaluated across a wide range of potential wind farm sites.



Minimum Ballasting Operations

Passive ballasting or de-ballasting is utilized during the platform installation at site. Once the platform is connected to the pre-laid mooring lines, no further ballasting or de-ballasting operation is required for the life time. This simple ballasting operation removes the risk of the ballasting system failure and has significantly lower life cycle cost compared to an active ballasting system.

Engineered for Constructability

Y-Wind consists of a simple structure combination of three columns and pontoons with no complex bracings and no deck. The Y-Wind structure is designed to enable fast and low-cost series fabrication in shipyards with standard procedures and equipment readily available. The structural arrangement of the foundation is based upon a stiffened panel assembly, which is the least costly offshore framing construction method.

Flexibility to select fabrication yard: The Y-Wind design requires smaller yard space and allows for local fabrication in many qualified yards. The optimized draft and breadth of Y-Wind fits many qualified fabrication yards worldwide.

Flexibility of Mooring System Selection with Low Cost

Station-keeping (mooring) system is the most critical item of Y-Wind for both its robustness and cost so that highly experienced engineers have been involved to access the Y-Wind functions under the various design load cases (DLCs) including power production, extreme and survival sea states.

Mooring line material (chain, wire, poly) and anchor type (drag, suction pile) will be selected depending on the site water depth and soil properties with minimal. The mooring options are iterated to derive the most cost-effective solution without reducing platform performance.

The current Y-Wind design uses non-redundant mooring lines with increased factor of safety recommended by ABS. With no changes to the overall design and minimal cost increase, additional mooring lines can be added to improve the redundancy if requested by operators.

Design Standards

The Y-Wind Semi platform is designed to fulfill the requirements of turbine performance, global performance, hydrostatic stability, structural integrity and longevity, mooring, power cable, and installation. The current Y-Wind hull and mooring design complies with *ABS Guide for Building and Classing Floating Offshore Wind Turbine Installations*, while the dynamic power cable meets the requirements in API 17J (or DNVGL-ST-0359). Design verifications covers the DLCs in ABS for the transit, power production, extreme and survival conditions. Relevant corrosion and marine growth developed in the design life are considered for the platform hull and mooring design, based on the ABS recommendations.

In addition, Y-Wind is engineered to limit the platform mean and maximum heel angles below 4 and 10 degrees, respectively during power production. Maximum accelerations are below 0.4g in the vertical and horizontal directions.

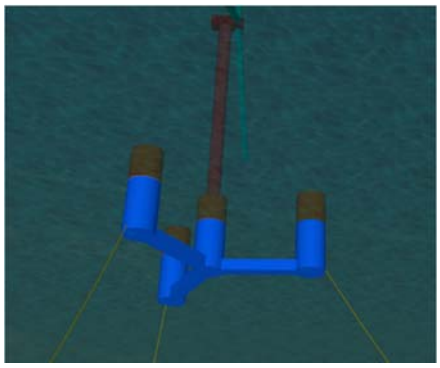
Other classification society rules can be accommodated for site specific wind farm developments.

Y-Wind 5MW Platform Particulars

Among the set of Y-Wind designs, a typical Y-Wind 5 MW platform is summarized in Table below. Y-Wind 5MW can be economically installed and operated at water depths of 40m and deeper.

Turbine Rated Power	5 MW HAWT
Design Life	20 years
Displacement	7,770 ton
Tower and Turbine Weight	600 ton
Design Draft	18.0 m
Quayside and Transit draft with Tower	5.3 to 5.7 m
Offset Column Center Radius	35.0 m
Column OD	10.5 m
Tower Base above SWL	10.0 m
Hub Height above SWL	90.0 m
Mooring Material	Chain, wire, polyester or combination
Mooring Type	Catenary, semi-taut or taut
Anchor Type	Drag or suction
Number of Mooring Lines	3
Water Depth	≥ 40 m

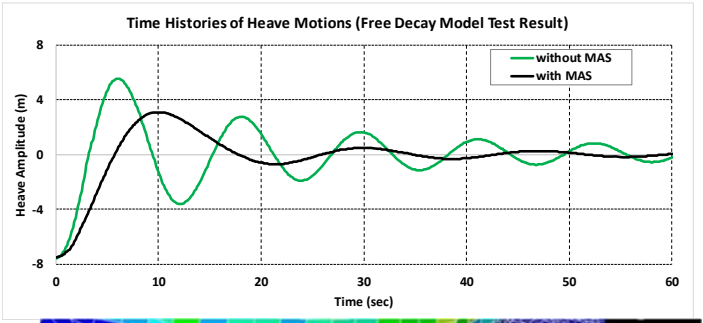
Y-Wind 5MW Design Validation



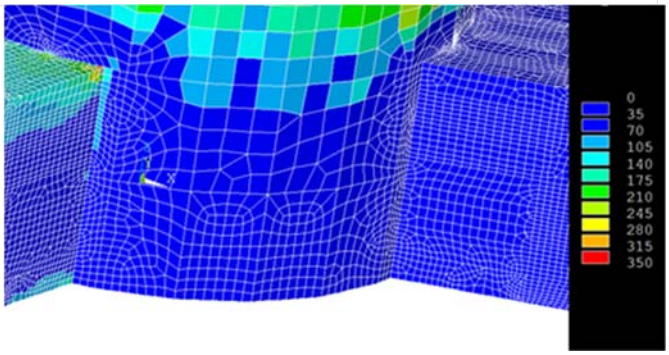
Y-Wind 5MW design has been validated through extensive simulations against the ABS offshore floating wind platform design criteria in hydrostatic stability, platform global performances, structural design, and mooring design. Representative US offshore metocean conditions with an assumed water depth of 200 m were utilized for the fully coupled analysis. However, these conditions may cover the conditions for the most offshore locations worldwide so that the current Y-Wind design can be directly used for those offshores, with minor modification if necessary.

Design Conditions		Wind	Wave		Current
		10 min. @ hub (m/s)	Hs (m)	Tp (s)	Surface (m/s)
Operation	Rated	11.4	7.5	11.5	0.4
	Cutout	25.0	8.5	12.7	0.6
Extreme	50-yr	40.0	12.5	14.2	0.8
Survival	500-yr	45.0	15.0	15.3	1.0

Naval architecture model testing: Model testing was also carried out to evaluate the MAS performances for the various configurations. The MAS are proven to be very excellent to dampen the platform motions.



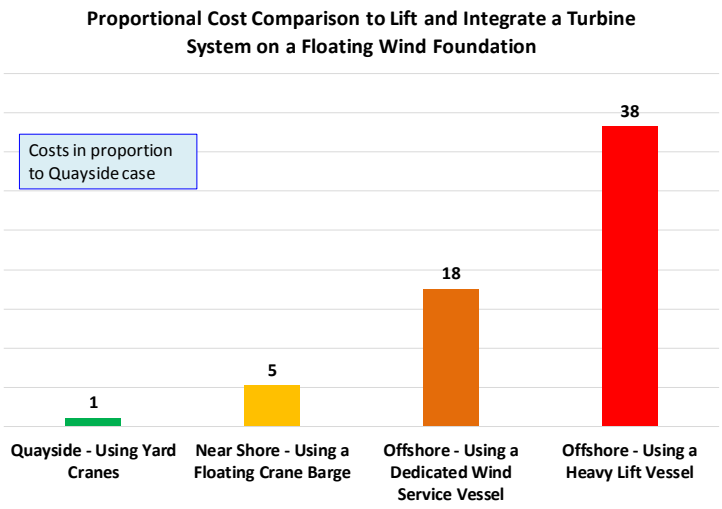
Structural Analysis: A global FEA structural model was developed and used to analyze operating, extreme and survival load cases. Model analysis confirms that the overall structural design including MAS is conservative. Platform structures could be optimized once a specific site for the platform is confirmed. Analysis confirms that critical pontoon and column connections stresses are within expected ranges and preliminary assessments indicate that the life of those critical connections will be within design requirements for the design verification case considered (200m water depth, US location).



Model review also suggests that further design refinement of secondary structures and will likely result in additional steel weight and hence cost savings.

Low Cost Operations for Tower Integration and Platform Installation

Quayside tower integration: The hull with its very shallow draft allows quayside integration of the wind turbine at most local shipyards or ports. Quayside lift and integration of the tower, turbine and blades are the lowest cost execution strategy. Other execution methods are between 5 to 38 times more expensive.

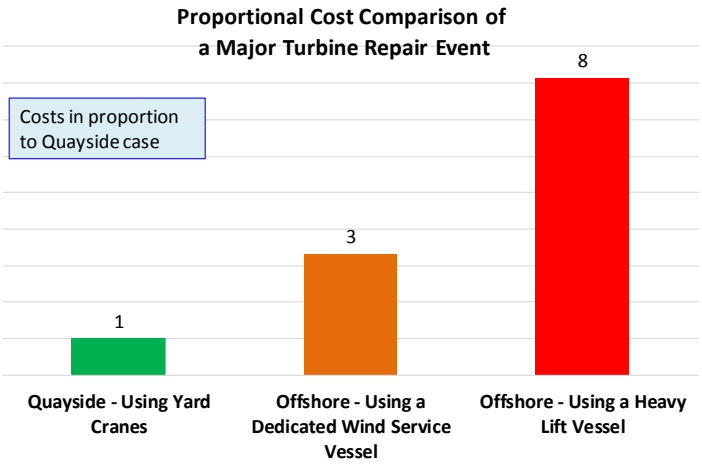


Flexible tow and installation operations: The Y-Wind platform can be towed into position by less costly and readily available tugs (vessels of opportunity). Shallow transit draft with sufficient self-buoyancy for stability during the tower integration, wet-towing, installation and repair provides high flexibility to use local low-cost vessels (tugs) for those operations. Minimal use of mooring line pulling winch enables quick and simple mooring line connection to the platform.

All these features contribute to produce a flexible execution design to realize the lowest possible execution (CAPEX) costs for a given wind farm site.

Lowest Cost Maintenance

On-site regular maintenance is expected like fixed wind foundations. However, for the case of major repair of the turbine, the shallow platform draft of Y-Wind also allows for quayside (or dockside) turbine maintenance. Dis-connectable mooring enables to bring the platform to quayside for major turbine maintenance and repair, if required.

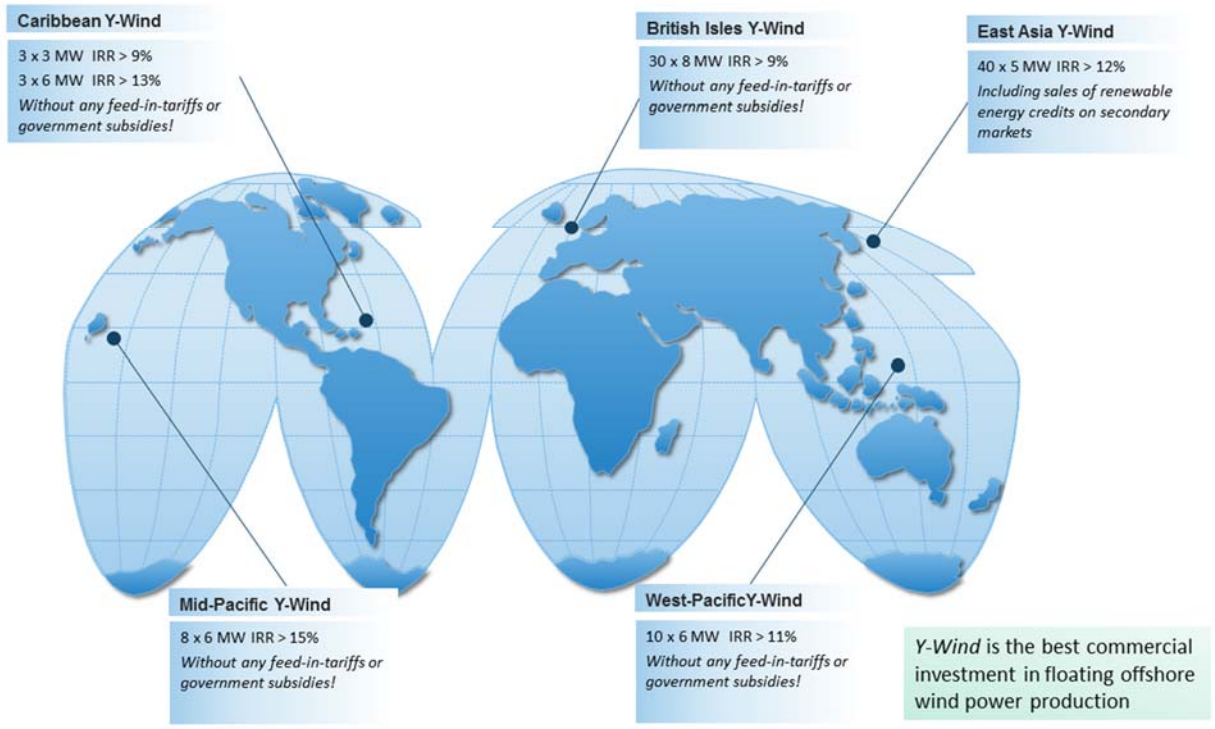


After quayside repair the Y-Wind platform is then towed back to site and reconnected to the mooring lines. Repair operations quayside are significantly less costly and less risky than undertaking repairs at site with a floating crane, or even in sheltered coastal water with a floating repair vessel. Major repair costs near shore or offshore are between 3 to 8 times more costly than completing repairs quayside (including towing of the platform from site to quayside to reinstalling at site).

All these features result in the lowest possible maintenance costs (OPEX) over the life cycle for a given wind farm site.

Economic Analysis - Internal Rate of Return (IRR) Estimates using Y-Wind

The engineering design for Y-Wind incorporated extensive analysis on achieving a superior performing floating foundation at the lowest cost possible. Expanding upon this cost analysis, VLO has completed economic analysis to assess the commercial suitability of Y-Wind for several potential floating offshore wind farms. Economic analysis incorporates local input in the construction, installation and support of Y-Wind, local economic conditions and conservative factors for the sites evaluated. The economic analysis suggests that Y-Wind is a commercially viable solution for many sites, today. Most applications of Y-Wind can be commercially viable without any government subsidies. Small numbers of Y-Wind will also be commercially viable; large numbers of Y-Wind units are not necessary to achieve economies of scale and commercial viability as is necessary with other foundation designs. A set of Internal Rates of Returns for some potential wind farm sites is provided in the following figure.



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