Compliant towers: the next generation

Well counts, design altering deepwater scenario

Steve Will
Mustang Engineering, Inc.

In the ongoing search for hydrocarbons offshore, a major challenge faced by operators has been to reduce field development costs. In deepwater and in marginal production areas, this challenge has led to the evolution of structural technologies.

In the past, costs dictated that central drilling and production facilities require either oil prices exceeding $18/ bbl or significant reservoirs larger than 100 million bbl of recoverable oil. It was predicted that oil production rates of 50,000-75,000 b/d would require 40 to 60 wells, as typical flow rates per well did not exceed 1,000 b/d.

The compliant tower (CT), based on earlier data, was deemed to be unsuitable for marginal field applications in water depths in the 1,200-2,500 ft range. With data accumulated from recent installations and subsequent cost studies, however, initial presumptions about well counts and flow rates in deepwater fields have been revised. Individual wells can generate flows exceeding 7,000 b/d, requiring single drilling rigs and fewer well slots.

Radical improvements in compliant tower design have reduced tonnages, improved constructability and enhanced operating capability, thereby reducing capex, opex, and schedules. These attributes make compliant towers a proven, viable alternative to floating systems for use in deepwater fields.

Tower compliancy

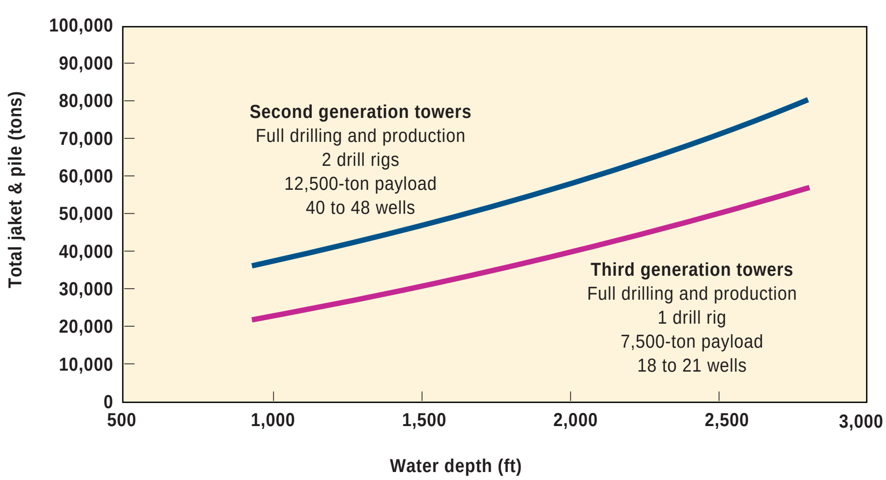
The term, compliancy connotes flexibility. In deep waters, bottom founded and floating structures must be designed to be "compliant" in order to mitigate the impact of hurricane forces of wind, waves and currents.

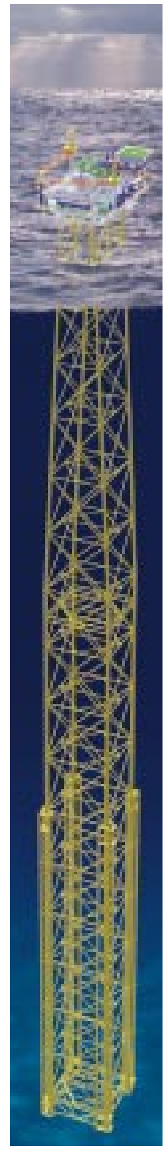
Under hurricane conditions, the time lag (period) between larger waves is approximately 13 seconds. In order to prevent excessive amplification of the environmental forces of wind, waves and current, it is imperative that the natural period of the primary modes of response be substantially different than the dominant periods of the hurricane seastate.

Achieving compliant response requires controlling the mass and stiffness characteristics to de-tune the natural frequencies of vibration, relative to the frequencies of the periodic forces of wind and waves, in combination with current.

Compliant towers, with the use of flex elements such as flex legs or axial tubes, typically achieve sway periods of 30-33 seconds. As a result, resonance is reduced and wave forces are de-amplified. By comparison, typical shallow water platforms will have periods of 3-4 seconds.

Tower weight versus water depth – Gulf of Mexico





The third generation of the compliant tower for the US Gulf of Mexico (Art by Mustang Engineering).

De-amplification of hurricane forces enhances efficiency levels with respect to tonnages and construction requirements, as the structure can be configured to adapt to existing fabrication and installation equipment and facilities.

Advances in design procedures have resulted in added savings with the third generation towers. Design and analysis software can accurately account for three dimensional random seas, including refinements for current blockage and conductor shielding. Wind forces can be accounted for dynamically, thereby reducing the levels of excessive conservatism which may occur when using conventional design procedures.

Finally, the use of response-based design criteria, which involves the determination of 100-year return period responses rather than metocean events, can help to ensure that the selected design environmental events will result in design force levels with acceptable, but not excessive, levels of risk.

Tower history

The compliant tower concept has essentially progressed through an evolution of three configurations.

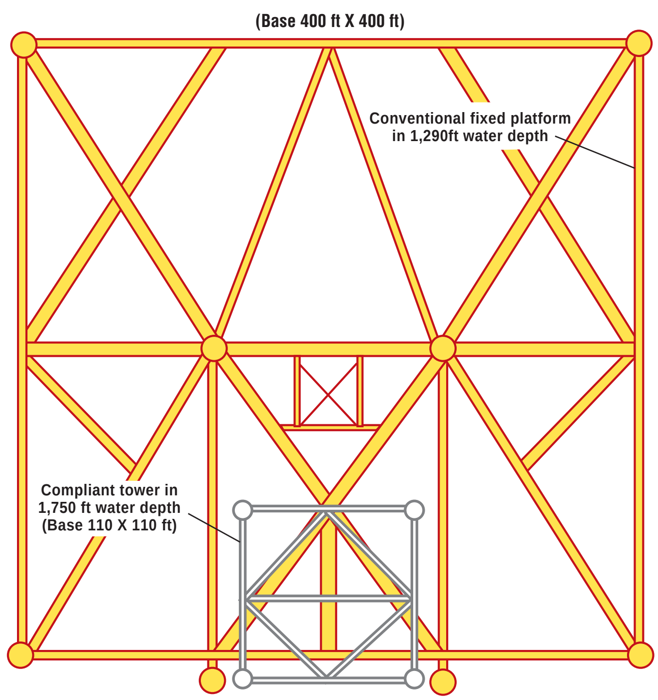
- The first emerged in the early 1980s with the installation of Exxon's Lena platform, a guyed tower in a water depth of 1,018 ft and supported by 20 weighted guy wires to achieve compliancy and stability.
- A second generation of structures, compliant piled towers, was introduced during the late

1980s which relied on the piles for its flexibility and stability.

- The newest generation of compliant tower designs is represented by the 1998 installation of: (1) Amerada Hess' Baldpate compliant tower at Garden Banks Block 260 in 1,650-ft water depths; (2) Texaco's Petronius tower, designed for installation at Viosca Knoll Block 786 offshore Louisiana in 1,754-ft water depths.

The Baldpate tower gained its compliance by utilizing axial tubes affixed to its legs and an articulation point approximately 500 ft above the sea floor. The Petronius structure, referred to as a flex-leg structure, relied on flexible legs for its stability and flexure.

Base footprints of tower and fixed platform



Operating advantages

The compliant tower (CT) offers many of the same advantages of any bottom-founded structure producing in shallower water depths. Additionally, the CT approach allows certain pluses when compared to floating methods. Among them are:

(1) Drilling and production operations: The compliant tower's topside structure enables drilling and production to be carried out simultaneously without the need for attendant mobile drilling equipment that can be difficult and expensive to contract. For example, the Baldpate platform's 9,800-ton total topsides weight included a tri-level deck section with a 28-man quarters and facilities sufficient to support an API 20,000 ft. drilling rig along with the processing equipment necessary to accommodate production from the 18 wells. Like the fixed platform, the CT can also support workover or well servicing operations without having to rely on external floating support equipment.

The compliant tower is very stable. Its displacement, even under 100-year hurricane conditions, might be only 25-30 ft, or 1.5-2.0% of the water depth. In contrast, floating systems generally have lateral movement of up to 10% of water depth. Spars, with riser constraints, have a maximum lateral displacement at the water line of approximately 6% of water depth.

The stability of the CT means that its downtime is limited to only the most extreme events, similar to shallow water platforms. This stability also reduces the complexity of operations. There are no specially-trained crews needed to operate ballast/deballast tanks or to adjust riser tensions. Because it is not a floating system, it does not require ABS classification.

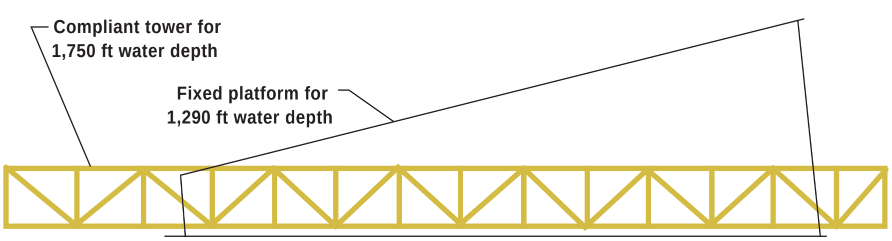
(2) Production riser and wellhead support: With the compliant tower, all wells can have dry trees in lieu of subsea wet trees. CTs can also serve effectively as a central production facility, supporting platform drilled wells or satellite subsea tiebacks. Also, wells can be predrilled and temporarily abandoned and tied back following installation of the tower. The surface completions improve accessibility for controls, maintenance and future well servicing.

Compared with floating systems, such as tension leg platforms (TLP), mini-TLPs, and Spars, the production risers are conventional and are subjected to less structural demands and flexing, as they are afforded maximum support and protection by the CT structure. This factor is particularly important in fields where high currents are prevalent, such as in the Campos Basin offshore Brazil.

The production risers use conventional well systems, with conductors and casings that become structural elements. Once again, the simplicity of the CT's operation reduces material costs. Production tubulars are generally made of carbon steel as opposed to special materials needed to support flexing. The weight of the risers extends directly into the seabed and, along with the wellheads and BOP stack, necessitates only minimum support by the jacket.

(3) Export riser support: The compliant tower has an advantage in that it can effectively support large diameter steel export risers, including steel catenary risers (SCR), J-tubes, or pre-installed risers. In the case of the Baldpate installation, the 16-in. oil and 12-in. gas SCRs were suspended from clamps attached to the jacket legs approximately 400 ft below the waterline, with the pipeline extending from the platform to touch the seabed nearly 650 ft from the structure's base.

Elevations of platform and tower



Comparisons, economics

Initial projections of tonnages for compliant towers have been revised downward following the design and construction of the Baldpate and Petronius towers. Earlier data suggested that the Baldpate tonnages would approximate 50,000 tons for the 1,900-ft structure operating in 1,650 ft water depths.

In actuality, a total of 34,000 tons of structural steel were used to construct the tower and the piles. This included the 351-ft base section weighing 8,700 tons and the 1,320-ft tower weighing 20,200 tons. By comparison, one conventional fixed platform, with higher well counts and payload and currently producing in approximately 1,350 ft water, weighed almost 60,000 tons.

Similarly, a second conventional fixed platform currently producing in 1,290 ft water depths weighed in at approximately 43,500 tons. Extrapolations from in-house studies indicate that compliant tower tonnages would allow operation at a water depth of 2,800 ft with a tonnage comparable to that of the 1,350 ft fixed platform and at a depth of 2,300 ft with a tonnage approximating the fixed platform in 1,290 ft depths.

The compliant tower's economic viability was further validated by the Baldpate installation. The capital expended for the development of the anticipated 118 million barrel of oil equivalent (BOE) reserves for the two primary Baldpate reservoirs is about $300 million, including development drilling and completions costs and pipelines. This translates into an approximate capital expenditure (capex) of $2.80 BOE. By comparison, it has recently been reported that the monohull mini-TLP in similar water depths had a capex of $3.50 BOE.

Improved constructability

The compliant tower is a more slender, less complex structure than is a conventional deepwater fixed platform. As such, it presents fewer fabrication constraints and more opportunities for economy. For example, when comparing footprints, existing deepwater structures for depths of 1,290 ft and 1,350 ft have base widths exceeding 400 ft. By comparison, the Baldpate structure has a base width of 90 ft, with the base expanding to 140 ft at the mudline.

The Petronius flex-leg structure has base and tower widths of 110 ft square. The dramatic reduction of tonnages and fabrication heights allows yard fabrication and assembly with a minimum of large capacity, heavy lift and extended reach cranes and specialized equipment. In addition, the reduced fabrication heights provide significant safety enhancements.

Reduced design force levels have also led to compactness. As a graphic example, the design footprint of the Baldpate tower was sufficiently compact to fit comfortably within the 140 ft by 200 ft launchbox created for the 1,290 ft jacket discussed earlier. In the Baldpate assembly, the largest members were the 144-in. diameter legs of 3 5/8-in. rolled plate. These material dimensions can be accommodated by multiple rolling mills and fabrication yards along the Texas/Louisiana Gulf Coast.

Construction complexity of compliant towers is minimal. The design of these structures is simplistic, with a square plan and repetitive framing used throughout the entire length of the tower section. There are no high cost mechanical system components required for long-term performance by compliant towers. Rather, all structural systems are composed of field proven, low unit cost materials and components which have been fabricated numerous times in fabrication yards experienced with the fabrication of offshore structures.

This relatively simplistic structure contains no items which have more complex construction requirements, such as buoyancy tanks, mooring systems, ballast/deballast systems, riser tensioners, or flexible risers. In short, compliant towers are simple to build and easy to maintain.

Installation

The installation procedures for the two-piece compliant tower are proven and can be handled by suitable launch barges residing in the Gulf of Mexico. Following the installation of foundation leveling piles on which the base is to be set, and two docking piles to guide the setting of the base, the base itself is launched and installed.

In the case of Baldpate, 12,400-ton skirt piles (three per base leg) were driven to a depth of 430 ft. Following the setting of the base, the tower was towed similarly by launch barge and launched end-on to then upright itself and be lowered by a derrick barge, having been ballasted to 900 tons.

The underside of each tower leg had a docking pin that stabbed into the receiving cones of the structure's base. Once positioned, it was additionally ballasted and connections grouted. Shortly thereafter, the deck was transported to the site and installed by the derrick barge in a single lift.

Subsequently, the main deck package including the quarters, was lifted and set on the deck. Following hookup of flow lines and facilities, first oil production was recorded within two months. Using Baldpate and Petronius as examples, the conventional manner in which the compliant tower can be installed, requiring no special equipment, adds to its attractiveness.

Conclusion

The improved efficiencies in field development have been produced by a combination of design advances, improved configurations and reduced wellcounts. Options now exist for centralized drilling and production with the design of new generation compliant tower configurations that are lighter, easier to fabricate and more economical to install.

These more efficient CT configurations provide a means of improving field development costs with these efficiencies translating into lower capital expenditures needed for the development of marginal deepwater sites. The discussions herein apply to towers designed for well counts of 18-20 and simultaneous drilling and production operations.

Mini-towers, designed for fewer wells (5-8) and reduced payloads (drilling or production only opereations) will offer added savings. Similarly, milder environments will also result in lighter, more compact configurations and reduced capex.

References

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Author

Steve A. Will, P.E., is senior consulting engineer at Mustang Engineering, Inc. Will has 31 years experience in offshore engineering and construction. His background includes project management responsibility for some of the world's tallest bottom founded structures. He is a graduate of Purdue University and is a registered professional engineer in Texas and Louisiana.