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Title: Seismic Response and Stability Analysis of Articulated Tower

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Abstract

The Offshore industry has moved towards deep water regions due to continuous depletion of oil and gas reserves at shallow to intermediate water depths. Conventional fixed jacket and jack-up type structures, large member sized gravity-style offshore platforms etc. have become uneconomical for deep water operations. The growing demand for deep water platforms has thus initiated the development of economical but equally reliable alternatives like compliant structures in the last two decades. Single Hinged Articulated Tower (SHAT) platform is one of the compliant structures which is economically attractive especially as loading and mooring terminal in deep waters. SHAT is favoured for deep sea water operations since it avoids unacceptably high hydro-dynamic loads by yielding to wave and current actions. It does not transfer any bending moment to the base leading to economic designs.

Most of the researchers in past have carried out dynamic analysis of the structure under Wave, Earthquake or Wind loads or a combination of these loads. But very few researchers have carried out Stability analysis of the structure. Present study has been specifically performed for Stability analysis of SHAT in transient / non-linear sea environment.

SHAT has been modeled as a stick and universal joint at base has been modeled as mass-less rotational spring. Since at each time step, the instantaneous submergence, inclination and geometry of the tower changes appreciably, the buoyancy, added mass, stiffness, hydrodynamic forces and damping also changes. Equations of motions become highly non-linear. Lagrange's method has been used to arrive at non-linear dynamic formulation of articulated tower. Wave forces on the submerged part of the tower have been estimated by the modified Morison's equations. The random waves have been simulated by Monte-Carlo Technique represented by Modified PM Spectra. Seismic inputs have been applied using El-Centro / Northridge spectra. The water particle velocities and accelerations have been stipulated by Airy's Linear wave theory. To incorporate the effect of variable submergence, Chakrabarti's approach has been adopted. The equations of motion were solved using numerical integration scheme to determine total transient behaviour of the Tower. The transient responses were further subjected to stability assessments using Concept of Minimum Potential Energy. In addition, two-dimension Phase Plots were deployed for determining steady state motion of the structure.

In addition to other findings, the Stability assessment showed that the high frequency energy contents of earthquakes are not attracted by the compliant tower. The tower tends to vibrate at its own natural frequency while the steady state response again takes place in wave frequency when the earthquake is over. The time required to achieve the steady state response after the duration of earthquake depends upon the sea environment i.e. nature / size of sea wave. High sea state dampens the seismic response quickly. In the absence of earthquake and other environmental loads, tower oscillations are checked by hydrodynamic damping due to waves and due to tower oscillation and inherent tower buoyancy.