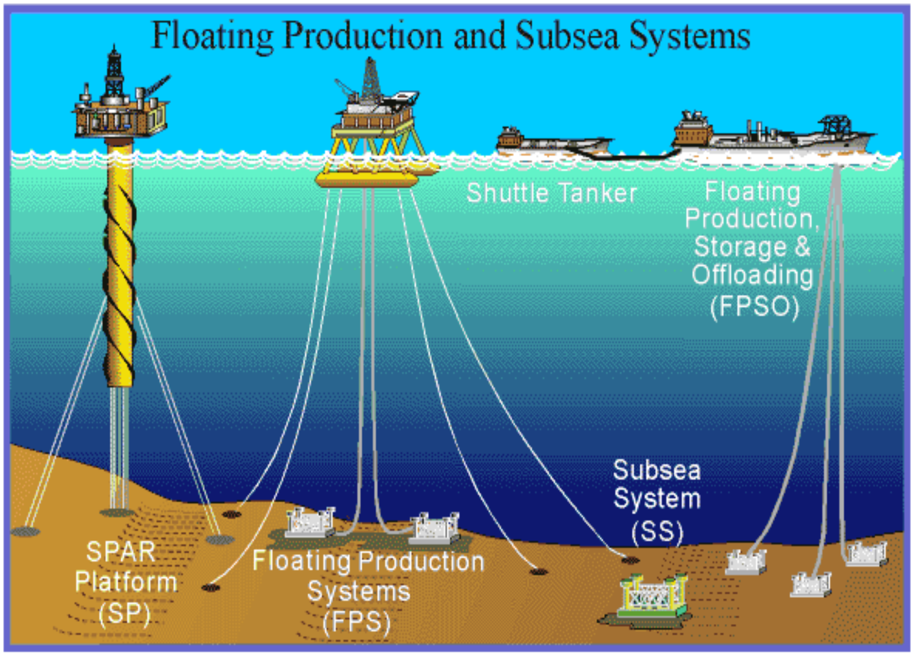
Control for Floating Structures in Offshore Engineering

The recent formation and growth of the global deepwater offshore industry has been driven by increased demand for oil and gas stemming from years of economic growth, reduced production in existing hydrocarbon fields, and depletion of shallow water reserves. These factors have encouraged operators to invest billions annually to chase this offshore frontier and the development of floating production and subsea systems as solutions for deepwater hydrocarbon extraction.

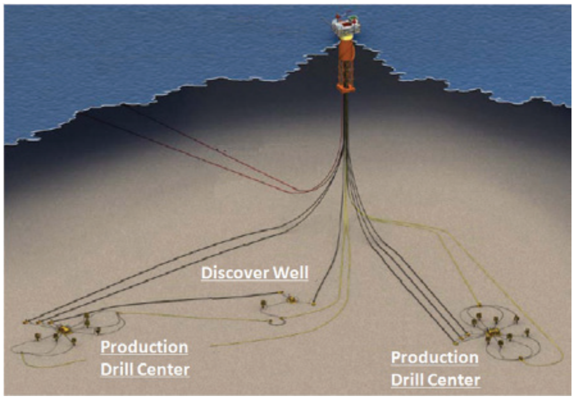
Currently, 15% of total offshore oil production is carried out in deep waters, and this proportion is expected to rise to 20% in the next few years. The harsher marine environment and need for subsea production systems in remote deepwater developments opens a set of challenges and opportunities for the control theorist and engineer.



Source: Minerals Management Service, U.S. Department of the Interior

A Critical Need for Technology

The April 2010 Deepwater Horizon accident in the Gulf of Mexico serves as a reminder of the risks and challenges in offshore operations. In the push toward exploration and production in deeper waters and harsher environments, control theorists and engineers working with colleagues in different disciplines will be challenged to forge a path forward with innovative technological approaches to safely supply the energy the world needs.



A view of the commercial subsea system (wells, manifold, and umbilical) on the seabed (Source: MMS Ocean Science, Nov. 2005)

Subsea Production Systems

Subsea systems must be installed accurately in a specified spatial position and compass heading within tight rotational, vertical, and lateral limits. The tolerances for a typical subsea installation are within 2.5 m of design location and within 2.5 degrees of design heading for large templates and are more stringent for the installation of manifolds into the templates.

Traditional subsea installation methods include the use of guidelines or the use of ship dynamic positioning and crane manipulation to obtain the desired position and heading for the payload. Such methods become difficult in deeper waters due to the longer cable between the surface vessel and subsea hardware when near the seabed.

An intuitive solution to alleviate the precision placement problem is the addition of thrusters for localized positioning when the payload is near the target site. Control of the dynamic positioning of the subsea payload is challenging because of unpredictable disturbances such as fluctuating currents and transmission of motions from the surface vessel through the lift cable.

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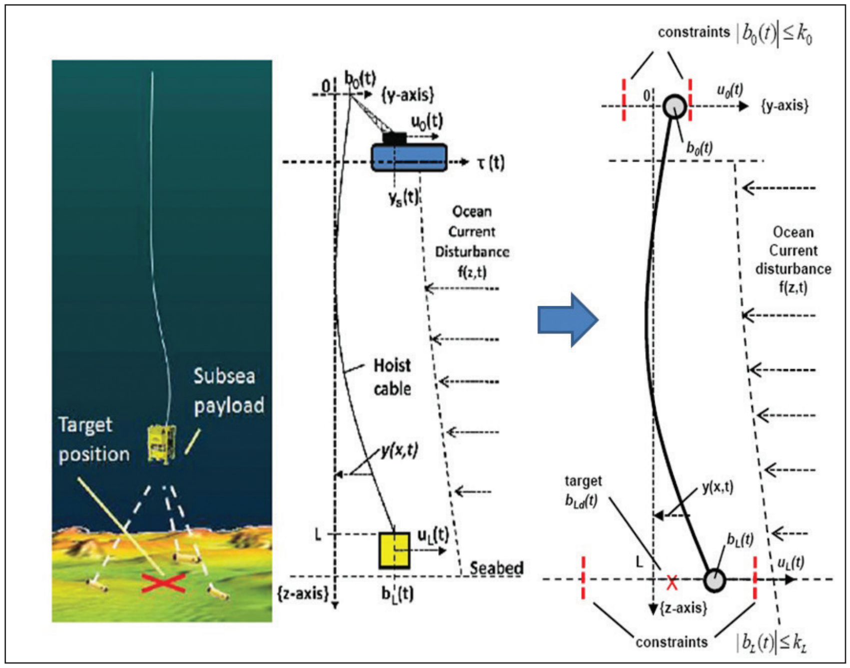
Dynamics of the Lift Cable

With the trend toward installations in deeper waters, the longer cable increases the natural period of the cable and payload system, which in turn may lead to increased pendulum-like oscillations. Time-varying distributed currents may lead to large horizontal offsets between the surface ship and the target installation site. Investigation of the dynamics of the flexible lift cable to aid in the control design and operation planning is desirable and challenging.

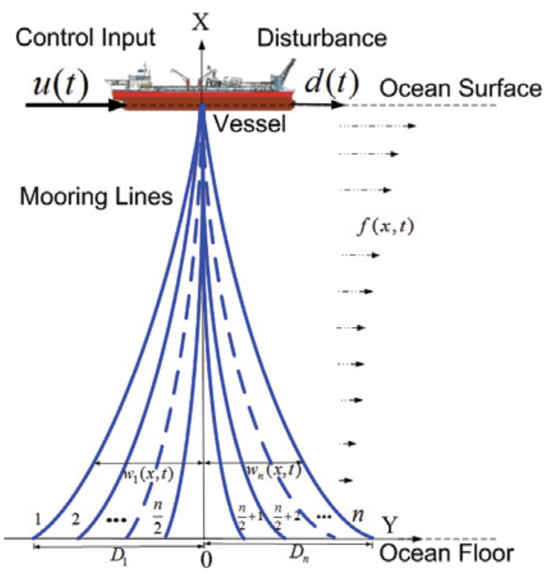


Positioning of the subsea hardware using thrusters (left), illustration of subsea positioning (center), and a schematic of the installation operation (right)

Thruster-Assisted Position Mooring Systems

Floating platforms, such as anchored floating production storage and offloading (FPSO) vessels with positioning systems, have been used widely. The two main types of positioning systems are dynamic positioning systems for free-floating vessels and thruster-assisted position mooring systems for anchored vessels. The thruster-assisted position mooring system is an economical solution for station keeping in deep water due to the long operational period in harsh environmental conditions. The thruster assistance is required in harsh environmental conditions to avoid the failure of mooring lines.

Mooring lines that span a great distance can produce large vibrations under relatively small disturbances, which will degrade the performance of the system and result in a larger offset from the target position of the vessel. Unknown time-varying ocean disturbances of the mooring lines lead to the appearance of oscillations, which make controlling the mooring system relatively difficult.



An FPSO vessel with thruster-assisted position mooring system