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# Development of a simulation method for the subsea production system

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**Abstract**

The failure of a subsea production plant could induce fatal hazards and enormous loss to human lives, environments, and properties. Thus, for securing integrated design safety, core source technologies include subsea system integration that has high safety and reliability and a technique for the subsea flow assurance of subsea production plant and subsea pipeline network fluids. The evaluation of subsea flow assurance needs to be performed considering the performance of a subsea production plant, reservoir production characteristics, and the flow characteristics of multiphase fluids. A subsea production plant is installed in the deep sea, and thus is exposed to a high-pressure/low-temperature environment. Accordingly, hydrates could be formed inside a subsea production plant or within a subsea pipeline network. These hydrates could induce serious damages by blocking the flow of subsea fluids. In this study, a simulation technology, which can visualize the system configuration of subsea production processes and can simulate stable flow of fluids, was introduced. Most existing subsea simulations have performed the analysis of dynamic behaviors for the installation of subsea facilities or the flow analysis of multiphase flow within pipes. The above studies occupy extensive research areas of the subsea field. In this study, with the goal of simulating the configuration of an entire deep sea production system compared to existing studies, a DES-based simulation technology, which can logically simulate oil production processes in the deep sea, was analyzed, and an implementation example of a simplified case was introduced.

*Keywords*: Subsea production; Discrete event simulation; 3D visualization; Fluid flow simulation

## 1. Introduction

### *1.1 Background of Subsea production system*

Oil and gas fields, which recently experience growing competition, have already reached a saturated state in inland areas, and thus the development area is being extended to coastal areas and the open sea that are distributed all over the globe. Accordingly, technologies and equipment for exploring and excavating the resources of deep sea areas that are buried underground under the sea have been gradually enhanced. Facilities that are used for the development of resources buried underground in coastal areas and the open sea are collectively prefixed with the term, subsea. The examples include subsea well, subsea field, subsea project, and subsea development. Figure 1 shows the configuration of the facilities for deep sea resource development, and Table 2 summarizes the explanations of major facilities. For deep sea oil field development, in 2003, ChevronTexaco Company succeeded in drilling down to a depth of 3052 m in Toledo in the Gulf of Mexico [1], which opened an era of 3000 m depth. A small number of advanced companies, which have high technical levels and know-how, are monopolistically maintaining a close relationship with oil major companies, and thus substa ntial difficulties are expected in market entry [2, 3].

Depending on the complexity of a system, subsea production systems can be classified into various types ranging from a system that consists of a single well that is connected to a fixed platform, FPSO, or an onshore platform through flowlines to a system in which a number of wells are connected to a manifold in a template or cluster form and transport oil to a fixed or floating platform or an onshore platform. When developing a reservoir that contains oil or gas, a subsea production system is used to continuously transport oil or gas to a floating platform or an onshore platform by drilling more than one well and installing appropriate deep sea facilities.

As the operation environment of this equipment corresponds to the deep sea or ultra-high deep sea, traditional equipment that has been previously used in offshore and onshore environments is not appropriate for this field development. Therefore, to collect oil and gas in the deep sea, equipment that is specialized for the deep sea needs to be developed; and for this equipment, the reliability of operation

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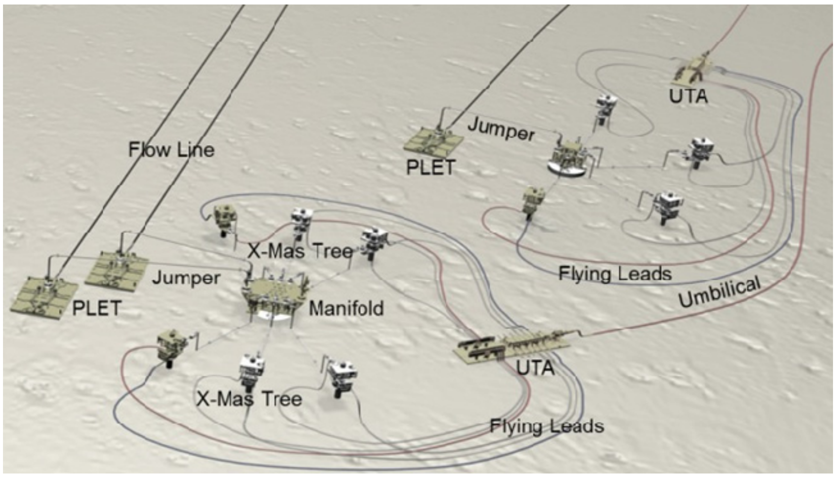


Figure 1. Typical configuration of a subsea production system.

without malfunction even in the deep sea environment is the most important. Only when this reliability is secured, economical excavation and collection of deep sea hydrocarbon resources are enabled.

The deep sea technology for natural resource production in the ocean is a specialized area, and is a field that requires high level of core technologies such as engineering and simulation. As most of the newly developed mine lots are gradually extended to the deep sea, relevant equipment and facilities require strict verification for the functions and requirements of various systems. In other words, special ships and equipment that are equipped with high-priced specialized equipment need to be operated, and thus a lot of cost and time are required to change existing ship/resource-related systems so that they can meet these demands. For the equipment operated in the deep sea, it is almost impossible to reproduce an operation environment as it stands, and thus a system integration test (SIT) for actual ship/actual equipment is almost impossible. Therefore, oil major companies and ocean/deep sea-related companies recently resolve this problem by finding out potential problems during installation/operation in advance through a virtual test using the newest engineering and information technologies. Using this newest simulation technology, it is possible to predict and verify the functions and dynamic behaviors of a system in advance in various conditions of the ocean and the deep sea. This approach is a model-based development methodology for an innovative high-tech plant and system solution; is an environment-friendly approach for the exploration and production of energy resources; and enables preceding evaluation and analysis of the dynamic behaviors of system components for resource production and distribution. Also, this simulation-based development methodology plays a role in providing an infra for the real-time virtual test of deep sea production, drilling, geological survey, and deep sea equipment installation/control.

For the simulation of the flow of subsea production, continuous behaviors of fluid and gas are implemented using a discrete event system (DES)-based commercial engine, and the simulation is performed by converting existing discrete events into discrete flow rate. For the stream of flow, a well becomes a fluid source, and oil or gas is created from this and is delivered to each tree. These fluids are gathered at a manifold through a flowline or a jumper. Then, it follows a scenario in which a selected resource is transported to offshore or onshore area through a production riser. For the linkage of the dynamic behavior and flow of subsea facilities, an architecture that can reflect the relation of dynamic behavior and flow behavior is implemented.

The results of this study could contribute to securing subsea production plant detailed design and manufacturing design packages in combination with the offshore facility design technology of existing domestic shipbuilding and marine engineering companies. Also, the results of this study could be used as the safety and performance prediction/evaluation module for supporting the integrated design of offshore plant and subsea production plant, rather than being used for existing simple operator education; provide data for the development of new processes and new products of subsea production plant; and contribute to securing smart field control-based technology, which is a new technology of recent ocean industry.

### *1.2 Previous research*

In Korea, research relevant to subsea production facilities is currently in an early stage. Most existing subsea simulations have performed the analysis of dynamic behaviors for the installation of subsea facilities [4] or the flow analysis of multiphase flow within pipes [5]. The above studies occupy extensive research areas of the subsea field. In this study, a case of a comprehensive subsea-related research topic was introduced. In his thesis, Devegowa [2] examined fundamental and important issues related with subsea resource development. Especially, a study on energy loss that could occur during subsea production depending on the design and operation conditions of subsea facilities was performed. For this, to