ABSTRACT

An integrated non-linear dynamic finite element system model was developed starting from the connection to the wellhead to the riser connection at the host facility including associated subsea structures. Due to high seismicity and soft soil condition, non-linear site response analysis was performed based on a finite element ground model to develop input seabed-level ground motions. Using these seabed-level site-specific ground motions, a time-history dynamic analysis of the integrated pipeline system was performed for the selected earthquakes based on the site-specific seismic hazard study. The non-linear time-history analysis could ensure adequate safety and bring design efficiency, particularly for pipeline system in highly seismic areas, crossing complex seabed features such as escarpments, and / or connected to sensitive / critical subsea structures. Other scenarios where a time-history analysis of the integrated system is essential are (1) a pipeline laid on liquefiable seabed, (2) a pipeline system containing buried and unburied sections, (3) a pipeline traversing variable ground conditions, etc.

KEY WORDS: Seismic hazard; Nonlinear soil response; Integrated model; Time-history; Subsea pipeline system, Site Response Analysis.

INTRODUCTION

Subsea pipeline system transports products from the offshore producing wells to the processing facility located either offshore or onshore and includes pipelines and subsea structures as well as connections to wellhead and risers. A study is undertaken to evaluate the behavior of an integrated pipeline system including associated subsea structures located in seismically active zone. The objective of the study is to evaluate the global performance of the pipeline system in addition to assessing component level integrity during strong seismic motions. The focus of the study was to address following specific concerns:

- Predict seismic behavior of pipeline system such as buckling, large localized displacements; leakage, rupture, etc.
- Assess pipeline system integrity such as overstress, overstrain, etc.
- Estimate pipeline seismic loading on connected subsea structures and foundations, risers, etc.

Details of seismic design requirements, input parameters, analysis methodology and the outcome of study are presented below.

SEISMIC DESIGN REQUIREMENTS

At present, there is a lack of industry guidelines specific to the seismic design of offshore / subsea pipeline system. The guidelines developed by American Lifelines Alliance, ALA (2001) and Pipeline Research Council International, PRCI (2004) primarily for onshore and buried pipelines are often used for seismic design of offshore pipelines. DNV-OS-F101 (2013) provides limited seismic design requirements for subsea pipelines but does not provide any specific design guidelines. The seismic design procedure and criteria for offshore structures developed by ISO 19901-2 (2004) are widely used in the oil and gas industry for seismic design of offshore pipelines although seismic performance and associated risks for offshore pipelines system and platform structures could be different. In this study, the seismic design criteria and procedure recommended in ISO 19901-2 (2004) have been considered for the pipeline system seismic design.

The seismic design has been performed considering two-level earthquake events: (1) Extreme Level Earthquake (ELE) with a return period of 400 years and (2) Abnormal Level Earthquake (ALE) with a return period of about 3500 years. The performance requirements for ELE and ALE vary; the ELE design dictates a strength based design requiring primarily elastic response of the system and its components during a seismic event. The ALE design is primarily performance (i.e. strain) based allowing non-linear plastic material / system behavior without a catastrophic system failure. The strength based criteria for the ELE pipeline design are selected as per ASME B31.8 (2012), as shown in Table 1 (for X65). Table 2 presents the strain-based ALE design criteria that are selected as per ALA (2001).