Decision-making support for reeled pipeline installation using a machine learning based method

Øystein Døskeland1, 2, Zhen Gao1, Yuri Novoseltsev2, Nicolas Holguin2
1 Department of Marine Technology, NTNU, Trondheim, Norway
2 Subsea 7 Norway AS, Stavanger, Norway

ABSTRACT

Installation of subsea pipelines used for transportation of hydrocarbons, water, or CO2, is carried out by ship-type installation vessels, which are highly sensitive to wave conditions. The prediction of installation loads in the pipeline is an essential input to the decision-making process for safe operation during offshore execution. Predictions may be required up to five days into the future. They can be produced from a physics-based simulation model with nonlinear calculations in the time domain and probabilistic representations of the response parameters based on multiple simulations for the forecasted wave spectra. Such calculations are computationally costly and, therefore, normally produced in advance by considering a set of generic parameter-based wave spectra. This paper describes how a machine learning model can be established, verified, and used to support decision-makers during a reeled pipeline installation operation. Compared to a physics-based simulation model, this method enables computationally efficient calculation of pipeline responses from forecasted wave spectra during offshore execution to provide more accurate input to decision-makers.

KEY WORDS: Machine learning; pipeline installation; modelling.

INTRODUCTION

Subsea pipelines are an essential part of the infrastructure required for offshore energy production and transportation. Some examples include transportation of oil and gas from a subsea production well to a production and storage unit, injection of water into a reservoir to control the well pressure, flowlines delivering oil and gas from an offshore field to an onshore terminal, transportation of hydrogen produced from offshore wind power to an onshore storage facility and transportation of CO2 from an onshore terminal for storage below the seabed. There is a significant need for such infrastructure also in the future.

The installation can only be done in operable weather conditions, meaning that the environmental conditions are sufficiently benign to avoid damage to the pipe or the installation equipment. Specialized monohull offshore construction vessels provide an efficient method for both transportation and installation of subsea pipelines, but monohull vessels are also very susceptible to wave conditions (especially wave period and direction) due to possible resonant motions. The process of classifying a condition as operable or non-operable typically includes dynamic structural analysis of the pipeline installation. This analysis is time-consuming, especially if a considerable number of environmental conditions and several time-domain simulations for each environmental condition need to be evaluated.

Offshore decision making for a pipeline installation project may be based on pre-determined environmental limits, often in terms of a limiting significant wave height (Hs) for a selected range of spectral wave periods (such as the spectral peak period, Tp) and mean wave direction. The calculated limits are then based on generic and parameterized wave spectra, such as JONSWAP (Hasselmann et al., 1973), which does not consider simultaneously occurring wave systems. In reality, both swell and wind sea systems are often present. The Torsethaugen wave spectrum takes into account both swell and wind sea systems but is limited to generic representations with coinciding directionality. In fact, the wave systems can vary significantly from the average/generic representations, and normally come from different directions.

Ship type installation vessels have natural heave, roll and pitch periods close to the main wave periods, leading to large resonant motions. A parameterized wave spectrum will often not capture the wave energy close to these periods well, leading to significant errors in the predicted vessel motion.

An alternative, and more accurate approach, is to base the decision-making on forecasted two-dimensional numerical wave spectra that are available closer to the time of execution. Whereas this approach is more accurate, it also requires a vast amount of analysis to be performed after the wave-forecast issuance to generate input for the decision-makers. Moreover, one needs to run multiple time-domain simulations with random waves for the same environmental condition to reduce the statistical uncertainty of the response parameters. Analysis that is purely based on FEM model simulations may not be feasible, because the wall clock time required for the simulations might not be tolerable.

Guarize et al. (2007) proposed a hybrid method for reducing the dynamic analysis simulation time for slender marine structures, introducing machine learning in the analysis process. Specifically, an artificial neural network (ANN) was trained from FEM based simulations, making it possible to generate long timeseries with relatively little computational effort. The scheme was applied to two cases: mooring line tension and...