ABSTRACT
Spar platform, a compliant floating structure, is well suited for deep water applications like drilling, production, processing, storage and off-loading of ocean deposits. It’s popularity is attributed to it’s economical performance and distinguished sea keeping characteristics besides various other merits. However, the analysis of Spar-mooring system poses tedious computational problems, primarily because of the uncertainties associated with the environmental loads, structural configuration and resulting nonlinearities. Spar is modeled as rigid cylinder, provided stability and stiffness by catenary cables attached to the cylinder at fairleads and spread out horizontally. Moorings, partly lying on the sea floor, hinged to the sea bed at the far end. Their contact with sea bed is properly modeled. The mooring lines in deep water conditions contribute towards significant inertia and damping due to their longer lengths, larger sizes and heavier weights. Coupled analysis, presently adopted, employs a fully integrated spar mooring system. A finite element model consists of a rigid cylinder linked and supported by tensioned mooring lines at fairleads. Hybrid beam elements are used to model the mooring lines experiencing large deformations and tension fluctuations of random nature. Their linkage with spar cylinder is suitably modeled through connector element provided in ABAQUS. It ensures integrated coupling and structural continuity. Spar hull is modeled as an assemblage of rigid beam elements connecting its centre of gravity, riser reaction point and mooring line fairleads. Monte carlo simulation is adopted to model the long crested random sea. The implicit solver employed is based on a step-by-step iterative time domain algorithm. The solver adjusts the size of time step to achieve accuracy and stability of the solution. Hence, the convergence of the solution is computationally intensive. Power spectra for various hull motions and maximum mooring tension are plotted and analyzed. Statistical characteristics of random response histories are also obtained. The integrated coupling shows a distinguished influence on the response behavior. The power spectra shows the participation of low frequency and wave frequency response behavior. The presence of current, however, influences the PSD’s in a significant way. The mooring tension response under moderate sea state shows the interaction of higher modes near wave frequency.

INTRODUCTION
The need for coupled analysis has long been recognized (Paulling and Webster, 1986). They used the 6-DOF non-linear motion equation for coupled dynamic analysis of a TLP. Ran and Kim (1997) studied the nonlinear response characteristics of moored Spar platform in regular and irregular waves. A series of experiments with 1:55 scale model were conducted in OTRC deepwater model basin with and without wind and current. Dynamic finite element code was developed and used to compare the coupled dynamic response with that due to uncoupled analysis. The studies on coupled analysis between a moored structure and its mooring system had been carried out by various investigators (Ormberg and Larsen, 1997; Ormberg and Larsen, 1998; Ran et al., 1999; Kim et al. 2001a, 2001b; Chen et al., 2001; Ding et al., 2003; Kim et al., 2005). They, in general, followed a similar approach, which was initially developed by (Paulling and Webster, 1986). In most of these traditional procedures of analysis, the force and displacement of mooring heads and spar fairleads are iteratively matched at every instant of time marching scheme in solving the equilibrium equations. However, the velocity and acceleration do not reportedly match. Further, the continuity of spar and mooring is missing.

The fully coupled integrated Spar-mooring line system used in the present study essentially means that the large spar cylinder is physically linked with mooring lines at fairleads provided by six nonlinear springs. This model is more realistic and has flexibility/scope to simulate the Spar mooring connection at fair leads. The mooring lines, as an integral part of the system, support the spar at fairlead and pinned at the far end on the seabed. They partly hang and partly lying on the sea bed. Sea bed is modeled as a large flat surface with a provision to simulate mooring contact behavior. The mooring line dynamics takes into account the instantaneous tension fluctuation and damping forces with time-wise variation of other properties. Drag, inertia and damping forces due to waves and current on mooring lines act simultaneously on Spar cylinder. Hence, there is no need of iteratively matching the force, displacement, velocity and acceleration at the fairlead position.

FINITE ELEMENT MODEL
In ABAQUS, provision of connector element facilitates the required continuity. These elements are made up of three translational and three rotational springs. Translational springs with higher stiffness model the rigid behavior while the three rotational springs simulate free rotation about respective axes. In actual field problems hydrodynamic loads due to wave and currents act simultaneously on Spar platform and mooring lines. In finite element model, the entire structure acts as a continuum. This model can handle all non-