

## Nonlinear Open-Close Loop Active Control of Articulated Leg Platform

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### ABSTRACT

A methodology is presented for implementing the nonlinear active control of compliant offshore platforms, such as the articulated leg platform (ALP), using feedforward and feedback gain (open-close loop) strategy. The nonlinear control law is derived by minimizing a higher order performance index, expressed as a function of the state variables and the control force. The state variables include angular displacement and velocity of the tower, and also the sea surface elevation and its integrands. The degree of nonlinearity of the control force is regulated by incorporating a nonlinear weighting factor in the control law. Both controlled and uncontrolled responses of the ALP are obtained by an iterative frequency domain technique which duly considers all the nonlinearities involved in the system. The response of a 180.5-m ALP is obtained for a random sea state under different, important parametric variations and is compared with those obtained by other control strategies.

### INTRODUCTION

Since 1972, when Yao first presented the concept of structural control (Yao, 1972), remarkable efforts have been made in controlling the linear as well as the nonlinear response of over-ground structures under wind and earthquake excitations. In recent years, the active control of compliant offshore platforms has attracted a great deal of attention by many researchers. As these platforms undergo large excursions under severe environmental loading, proper control of such large displacements is desirable from the safety and serviceability point of view.

Linear active control has mostly been applied to linear systems (Abdel-Rohman and Leipholz, 1978; Chang and Soong, 1980). Some of the researchers have extended it to nonlinear systems as well (Masri et al., 1981; Abdel-Rohman and Nayfeh, 1987; Kamat, 1988). Nonlinear active control of structures has also been addressed by a few researchers. Shefer and Breakwell (1987) employed a stochastic dynamic program to obtain the nonlinear control law which truncates terms higher than third order in the control force. Suhardjo et al. (1992) used Buric's method (Buric, 1978) for the nonlinear control of a duffing system. Recently, Wu et al. (1995) introduced a higher order performance index to obtain an optimal nonlinear feedback control law and implemented it to control the responses of multistorey buildings. It was shown that the nonlinear control is more effective than the linear feedback control in reducing the peak responses.

Applications of these control strategies to flexible offshore structures have not been widely reported. However, studies have been carried out to implement the linear active (close loop) control to tension leg platforms (Reinhorn et al., 1986 and 1987). The active control of multihinge articulated towers has also been discussed experimentally (Yoshida et al., 1990). Suhardjo et al. (1992) used a nonlinear feedback control for the tension leg plat-

form in which a quartic performance function is minimized to obtain the control strategy.

Most of the linear and nonlinear active controls use feedback (close loop) control strategy. For the seismic control of building structures, it has been shown that a combination of the feedforward and feedback (open-close loop) control proves to be more effective than the close loop control (Sarbjee and Datta, 1998). The application of the concept of feedforward and feedback control for the response reduction of an articulated tower like an offshore structure was first demonstrated by Yoshida et al. (1990). They described an experimental setup to control a model tower under a simulated random sea environment. The control force to be applied was calculated using a linear control law, and it required the measurements of structural response and wave height. Recently, Suneja and Datta (1998) also presented a linear open-close loop control strategy for controlling the response of an articulated tower under a random sea state.

Here, a nonlinear open-close loop active control strategy is presented for the control of the response of an articulated leg platform (ALP). The control law is derived by minimizing a higher order performance index. The response of the ALP is obtained by an iterative frequency domain technique which is used to tackle the nonlinearities involved in the system. Using the proposed nonlinear control strategy, the responses of an ALP are obtained under different, important parametric variations and are compared with those obtained by other control strategies. The open-close loop control strategy proposed here differs from that presented by Yoshida et al. (1990) in the theoretical computation of the control force. The latter study obtains the feedback gain control through the use of the standard Riccati solution and calculates the feedforward control force by solving a separate first order differential equation which uses the result of the Riccati solution. In the present formulation, the random wave is modelled as a double filtered white noise. The filter coefficients govern the predominant frequency contents of the wave. The filter equations are augmented to the equation of the motion of the system, and the control problem is formulated with state variables containing both structural motions and the integrands of sea surface elevation. The

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