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Dynamic Analysis of Non-Linear Structures by the Method of Statistical Quadratization

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ABSTRACT

Stochastic linearization is perhaps the most frequently used analytical method for analyzing the response of many nonlinear systems, as it provides reasonable estimates of the mean square response. However, the method is not, in general, well suited for estimating the power spectra of stationary responses of randomly excited nonlinear systems. In addition, for a Gaussian excitation, the linearized solution leads to a Gaussian probability distribution, whereas the true response is non-Gaussian. In this study, a higher order method termed equivalent stochastic "quadratization" is proposed to circumvent these shortcomings. The nonlinearity is replaced by a polynomial expansion up to a quadratic order. In this manner the Volterra series method can be used to approximate the response of the resulting nonlinear system. The system excitation is assumed to be Gaussian. However, the response is described by a non-Gaussian probability distribution. The method is developed for analyzing the stationary response of single and multi-degree-of-freedom systems; pertinent instructional examples are included. Further, a useful practical application of the proposed method is pursued for analyzing the stochastic response of compliant offshore platforms due to nonlinear drag forces. These are structures used to exploit oil resources in great water depths. The compliant nature of these platforms introduces nonlinear behavior which can not be neglected as in conventional offshore platforms. The method is applied for analyzing a specific three-degree-of-freedom model of a Tension Leg Platform (TLP) subject to wave and current forces. In addition to nonlinear drag forces, nonlinear potential forces significantly affect the TLP response. These forces are derived in the form of second order Volterra series. A stochastic response analysis of the TLP system due to combined nonlinear drag and nonlinear potential forces is performed to evaluate the relative significance of these forces.

The analytical results produced by the equivalent quadratization method for the instructional and practical problems considered, are found in good agreement with pertinent numerical data generated by Monte Carlo studies.

Clearly, the concept of quadratic, or even higher power, polynomial approximation of arbitrary nonlinearities and subsequent application of the Volterra series expansion for determining the random response of the derived equivalent nonlinear system, appears to be quite promising and meritorious. However, it is noted that the present study is strictly preliminary in nature, and reporting its findings in the present format conforms with the objective of the Lecture Notes in Engineering Series. Additional research is required to address versatility, reliability, and efficiency issues.

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