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# Dynamic reduction-based structural damage detection of transmission towers: Practical issues and experimental verification

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ABSTRACT

Structural damage detection in large-scale three-dimensional spatial structures is a challenging problem. It is impractical to develop a general damage-detection method that is applicable to all types of structural systems and all kinds of damage. A practical and efficient structural damage detection method must consider the characteristics of the target structure and damage in the development stage. In 2009, Yin et al. [33] proposed a damage detection method for the health monitoring of transmission towers. The method was developed based on the dynamical finite element (FE) model reduction technique, which utilizes identified modal parameters, such as natural frequencies and mode shapes, with only a limited number of sensors. In Ref. [33], the proposed method was numerically verified by simulated noisy data from a three-dimensional transmission tower model for single and multiple damage cases. This paper discusses some practical issues related to the proposed method, such as sensor placement and computational efficiency. Rather than proposing a general sensor placement method, a set of preliminary sensor locations is determined based on engineering judgement. This set of sensor locations is then checked against the results of a sensitivity analysis to ensure that the measured data contain information for identifying all of the target damage scenarios. To reduce the required computational power, two simplified versions of the proposed method are presented. The proposed method is then verified with a scaled-down model of a transmission tower (2.4 m high) that was built at the Structural Vibration Laboratory (SVL) of the City University of Hong Kong. This paper reports the detailed experimental setup and the method of extracting the modal parameters from a series of free vibration tests with only a limited number of sensors. The verification results show that the proposed damage detection method identifies the damaged sub-structures in all of the experimental cases considered. It must be pointed out that the transmission tower structure, in its operating conditions, suffers from the effect of the forces transmitted from the cables it carries. The influence of this force on the damage identification result is great and can not be neglected in practice. In the present experimental case study, only a transmission tower-like structure without carrying the cables is investigated in laboratory conditions.

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## 1. Introduction

Telecommunication and electrical power transmission towers play an extremely important role in the development of national economies and societies worldwide. The design of transmission towers is usually governed by wind loading, as this type of structure tends to be sensitive to wind action. The collapse of transmission towers due to accumulated damage is not uncommon, especially after typhoons and earthquakes. When such collapses take place, there usually follows a cascade of failures involving several adjacent towers along the line. A substantial number of failures of transmission line structures have occurred around the world, and the interruption of electrical service that results can have devastating economical and social consequences.

The structural safety and reliability of transmission towers has received much attention from researchers in recent decades [1,2]. Many studies have focused on the vibration behavior of transmission towers under wind action [2–4] and seismic ground motion [5]. Some researchers have utilized nonlinear analysis techniques to predict the ultimate behavior and failure load of transmission tower structures [6,7]. However, to the best knowledge of the authors, the assessment of the health status of this type of structure has seldom been addressed in the literature. Moreover, in the traditional design of transmission towers, secondary braces are usually neglected to simplify the analysis. As this does not match the exact structural characteristics of transmission towers, current models cannot reflect the load paths of real structures. The

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