PHYSICAL SYSTEMS FOR THE ACTIVE CONTROL OF TRANSFORMER NOISE

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CONTENTS

ABSTRACT

Traditional means of controlling sound radiated by electrical power transformers involve the construction of large expensive barriers or full enclosures, which cause maintainability and cooling problems. One promising alternative is to use active noise control to cancel the noise.

This thesis is concerned with one of the many problems which need to be investigated to develop a practical active noise cancellation system for transformers. This work, in particular, is concerned with the physical system design which includes the selection of the control source types and the evaluation of the near-field sensing strategies.

Loudspeakers have been widely used in the past as an acoustic source for canceling transformer noise. The principal disadvantage of using loudspeakers is that to achieve global noise control, a large number, driven by a multi-channel controller, are required. However, if large panels are used in place of loudspeakers as control sources, it is possible that the number of the control sources and complexity of the controller could be reduced substantially. In addition to reducing the number of control sources and simplifying their application, panel sound sources could also overcome some disadvantages of the loudspeakers, such as limited life and deterioration due to the weather. Thus, part of the work described in this thesis is concerned with the development of a resonant curved panel with a backing cavity as an acoustic type source. The advantages of using a curved panel rather than a flat panel are twofold: first a curved panel is more easily excited by the extensional motion of the piezoelectric patch actuators; and second, it is more difficult to adjust the resonance frequencies of the efficient modes of a flat panel than of a curved panel. The analytical models for the design of the panel cavity systems have been developed. As an example, a resonant curved panel with a backing cavity system was constructed and the sound radiation of the system was measured. Results show that a resonant panel-cavity sound source could be used as an alternative to a number of loudspeakers for active cancellation of electric power transformer noise. Due to the advantages of using the vibration type control sources, two types of vibration control sources (inertial electrodynamic shakers and piezoelectric patch actuators) were considered and the mechanical output of the inertial shakers has been compared with that of the piezoelectric actuators. In contrast with the piezoelectric actuators, the resonance frequencies of the inertial shakers can be tuned to the frequencies of interest using simple tuning procedures, so that the output efficiency of the shakers can be increased. The output performance was evaluated for two types of actuators by measuring the structural response of either a panel or a transformer when excited by the actuators at half their rated voltage input. Results demonstrated that a much larger output amplitude at the frequency of interest can be achieved by the tuned inertial type actuators.

Two near-field sensing strategies, the minimization of the sum of the sound intensities and the minimization of the sum of the squared sound pressures, have been studied. A quadratic expression was derived for the minimization of the sum of the sound intensities in the near-field. To evaluate the control performances achieved using both sensing strategies, a flat-panel was modelled with a harmonic point force disturbance and several point force control sources. Simulation results show that the control performance could be improved by minimizing the sum of the sound intensities in the hydrodynamic near-field, provided that a very large number of error sensors were used, otherwise better results were achieved using near-field squared pressure sensing.

Both sensing strategies were used to predict the noise reductions that resulted for the active noise control of a small transformer in the laboratory environment and for a large electrical power transformer on site. To optimize the locations of the control sources (for the large transformer on site) and the locations of the error sensors (for the small transformer in the laboratory environment), a genetic algorithm (GA), which is an evolutionary optimization technique, was employed as a search procedure to optimize the control source and error sensor locations. The results showed that the control source locations and/or the error sensor locations must be optimized to achieve the maximum sound reduction for either error sensing strategy, especially for the sound intensity minimization; otherwise, the sound field level may increase after control due to the character of the cost function (the sum of the sound intensities).

The simulation results were experimentally validated for the small transformer in the laboratory environment. Due to the limitation of the number of controller channels, the control performance was only evaluated for squared pressure minimization. The results demonstrated that for the case of 8 control sources and 8 error sensors, at 100 Hz, an average sound pressure reduction of 15.8 dB was achieved when evaluated at 528 monitoring locations at 0.25 m intervals on a surface that surrounded the transformer.

DECLARATION

The work presented in this thesis has not been submitted, in full or in part, for another degree at this or any other institution. The contribution of others to the content of this thesis and all previously published material has been fully acknowledged. I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

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LIST OF FIGURES

LIST OF TABLES