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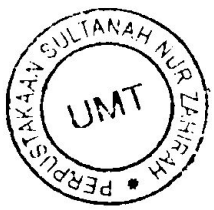

Frequency Weighted Model Order Reduction Techniques

by

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A thesis submitted to the School of Electrical, Electronic and Computer Engineering in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Faculty of Engineering, Computing and Mathematics

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Statement of Originality

The contents of this thesis are the results of original research, and have not been submitted for a higher degree at any other university or institution.

Much of the work in this thesis has been published for publication in refereed international conferences Chapters 3-5 of this thesis are based on the work described in these papers.

Refereed International Conference Papers:

- Wan Muda W.M., Sreeram V. and Iu H.C., "Passivity-Preserving Frequency Weighted Model Order Reduction Techniques for General Large-Scale RLC Systems", *11th International Conference on Control, Automation, Robotics and Vision*, Singapore, pp. 1310 - 1315, Dec 7-10, 2010 (Chapter 5).

- Wan Muda W.M., Sreeram V. and Iu H.C., "Frequency Weighted Balanced Truncation with Special Weight", *8th Asian Control Conference*, Kaohsiung, Taiwan, pp. 1443 - 1448, May 15-18, 2011 (Part of Chapter 3).

- Wan Muda W.M., Sreeram V. and Iu H.C., "An Improved Algorithm for Partial Fraction Expansion Based Frequency Weighted Balanced Truncation", *American Control Conference*, San Francisco, California, USA, pp. 5037 - 5042, June 29 - July 1, 2011 (Chapter 4).

- Wan Muda W.M., Sreeram V. and Iu H.C., "An Improved Algorithm for Frequency Weighted Balanced Truncation", *50th IEEE Conference on Decision and Control and European Control Conference*, Orlando, Florida, USA, pp.7182 - 7187, December 12-15, 2011 (Part of Chapter 3).

My doctoral studies were conducted under the guidance of Professor Victor Sreeram as my supervisor.

The research described in this thesis is the result of a collaborative effort with my Ph.D supervisor Professor Victor Sreeram and Professor Herbert Ho Ching Iu, and professors from Carleton University Ottawa Canada, Professor Ramachandra Achar and Professor Michel Nakhla, and Mr. Behzad Nouri. However, majority of the work is my own.

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Abstract

This thesis investigates the frequency weighted balanced model order reduction problem for linear time invariant systems.

First, two new frequency weighted balanced truncation techniques based on zero cross-terms are proposed. Both methods are applicable for single-sided weighting, and are based on modifications to Sreeram and Sahlan's technique. The first method uses the properties of all-pass function to transform the original frequency weighted model order reduction problem into an equivalent unweighted model reduction problem, while in the second method, the relationship between the final and the intermediate reduced order model used in Sreeram and Sahlan's technique is derived. Numerical examples show that a significant error reduction can be achieved using both methods.

Second, we present an improvement to frequency weighted balanced truncation technique based on well-known partial fraction expansion idea. The method yields stable reduced-order models for double-sided weightings. Two numerical examples including a practical application example, show a significant improvement over the other well-known techniques.

Lastly, we present passivity preserving frequency-weighted model order reduction techniques for general large-scale RLC (resistor-inductor-capacitor) systems. Three well-known frequency weighted balanced truncation techniques (Enns', Wang et al.'s and Lin and Chiu's), which preserve only stability and not passivity are generalized

to include passivity. Conditions under which the passivity is preserved are also derived. Four practical examples are given to show the validity and effectiveness of the proposed algorithms using different weighting functions.