NONLINEAR ADAPTIVE CONTROL IN THE DESIGN OF POWER SYSTEM STABILISERS

by

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Contents

Abstract.

This thesis is concerned with the development of nonlinear adaptive power system stabilisers for single-machine infinite-bus power systems. Single-input single-output design methods are discussed. The studies of this thesis cover the areas of linear adaptive, nonlinear optimal, nonlinear adaptive, and bilinear adaptive control in the design of such stabilisers. Both theoretical analyses and simulation studies are presented for each area of study.

The modelling of the single-machine infinite-bus power system is discussed for the purposes of the analysis and design of the linear and nonlinear optimal/adaptive power system stabilisers, and the simulation studies for the evaluation of the stabilisers that result from the various control strategies. The weighted minimum variance control scheme is selected for the development of the various power system stabilisers for the sake of simplicity and consistency. A linear adaptive power system stabiliser is designed, and its performance is taken as a *reference* for the assessment of the nonlinear power system stabilisers. The validity of the reference is verified by comparison of its damping performance with that of a well-designed, robust, conventional power system stabiliser at various operating conditions.

A new nonlinear model which describes the relationship between the excitation control input and electrical torque output is derived from the mathematical description of the nonlinear power system of concern. The model is given in a regression equation form, linear in the parameters and in the control input, with additional feedback signals. The model is an accurate characterisation of the inherent nonlinearities of the power system, and provides a useful means for the development of a variety of nonlinear control laws for power system stabilisers.

New nonlinear optimal control laws (namely the generalised minimum variance control law and its special case, the weighted minimum variance control law) are developed from a general form of the cost function; the associated global closed-loop stability properties are established theoretically. A number of nonlinear adaptive control algorithms, in the sense of different tuning strategies, can be developed from proper selections of the weighting polynomials in the cost function.

New nonlinear adaptive weighted minimum variance control algorithms are derived, and the theoretical proofs of the convergence of these algorithms are given. This completes the

theoretical development of the nonlinear weighted minimum variance control scheme based on the new nonlinear model.

For practical implementations, simplifications of the nonlinear adaptive control algorithm are discussed. A new bilinear model that represents the simplest nonlinear relationship between the control input and output is derived. This model retains the inherent nonlinearities of the power system and requires a minimum set of measurable feedback signals. New simple bilinear optimal and adaptive control strategies for the design of power system stabilisers are studied. A new bilinear adaptive weighted minimum variance control algorithm is also developed.

Three new power system stabilisers based on the *same* (weighted minimum variance) control scheme but *different* (nonlinear optimal, nonlinear adaptive, and bilinear adaptive) control strategies are proposed. Systematic evaluations and comparisons of the performance of these power system stabilisers against the reference performance of the linear adaptive power system stabiliser are conducted through simulation studies. Conclusions of the advantages and disadvantages of the different control strategies, involving the areas of *linear* and *nonlinear* as well as *optimal* and *adaptive* control, in the design of power system stabilisers are drawn from the studies. The results of this work provide a basis for the development of a practical nonlinear adaptive power system stabiliser.