Abstract

The aim of the research work undertaken is two fold:

Firstly – to develop new optimization based controller design techniques based on an approximate model matching concept, and secondly – to apply the developed methods to design of Load Frequency Controller (LFC) and Power System Stabilizer (PSS) for power system control.

In this work, the emphasis is on developing frequency-domain techniques for the controller design problem. Prevalent Pade type techniques for reduced order modelling and controller design rely on approximating certain system parameters called the Time Moments (TM) and Markov parameters (MP). Time Moments and Markov parameters of a transfer function $G(s)$ are proportional to the coefficients of its Taylor series expansion about $s = 0$ and $s = \infty$ respectively. It has been found that matching respective time moments of two systems leads to good low frequency matching of their behavior while matching the Markov parameters ensure good high frequency matching

Controller design methods for both single-input single-out (SISO) and multi-input multi-output (MIMO) systems have been proposed by matching new sets of system parameters called Approximate Generalized Time Moments (AGTM) and Approximate Generalized Markov parameters (AGMP), as detailed in the thesis. In this work, the range of these expansion points have been extended to be any real, complex, positive or negative and may lie anywhere in the four quadrants of the s-plane. An algorithm has been developed for finding the number and position of required expansion points which depends on the number of unknown controller parameters. Another important contribution of the work is in finding the best ('optimal') points of expansion while ensuring stability, robustness and other engineering specification set by the user.

An Optimal Pade Algorithm (OPA) for controller design has been proposed in which the expansion points are roots of a polynomial. In the present work, the problem of selection of the polynomial coefficients is formulated as a constrained optimization problem so that the desired performances are met as specified by a model while guaranteeing the closed loop stability. The proposed optimal Pade algorithm has improved the Lucas method of model order reduction by removing the restriction placed on the lower and higher order transfer functions and provides a generalized approach for the controller design using the model matching concept.

A direct controller parameter tuning (DCPT) method has been developed in which the controller parameters are directly optimized. The controller parameters are tuned such that the closed loop system matches the desired specification. Different ways of specifying the desired performance has been examined.

- The desired closed loop specifications are given in the form a model transfer function (matrix). The error between the response (responses) of the closed loop system and that of the desired model are minimized while satisfying constraints of system stability.
- The desired closed loop specifications are formulated in form of asymptotes.

- The closed loop time response are restricted to lie within a specified upper and lower bound while minimizing a quadratic performance index.
- The closed loop poles are restricted to lie within a wedge shape region in *s*-plane to achieve the desired degree of stability and performance.

The present work has used a combination of Luus-Jaakola (LJ) random search procedure and Genetic Algorithm (GA) for solving the constrained optimization problem while considering different types of performance indices and constraints. The LJ optimization procedure requires a good, feasible starting point. This drawback has been overcome by initially using the GA for searching a feasible solution point and then switching over to the LJ optimization procedure.

A low order equivalent controller design method using a Pade type approach of exact model matching has been proposed in which a least squares solution is obtained by using pseudo-inverse. However, unlike the AGTM matching method, OPA and DCPT method, stability of the closed loop system is not guaranteed. This approach depends on the choice of the desired model and controller structure.

The design methods developed in this work have been used for:

1. Controller design using the concepts of model matching and synthesis equation.
2. Controller order reduction problem in which higher order controller are designed using standard Linear Quadratic Gaussian (LQG) procedure.
3. Determining optimum weighting matrices in the LQG design procedure.
4. Robust sub-optimal controller design in which the state feedback controller, design by Linear Quadratic Regulator (LQR) design procedure, is replaced by an output feedback controller.
5. Determining optimum weighting matrices in the optimal model tracking controller design procedure.
6. Sub-optimal model tracking controller design by model matching methods of AGTM matching method, OPA and Pseudo-Inverse Approach (PIA).
7. Two degree of freedom (2-DOF) controller design.
8. Controller design for interval systems
9. Partial state feedback sub-optimal controller design.
10. Controller parameter optimization for optimum stability region

The AGTM matching method, OPA and DCPT method for controller design developed in this work does not have any restriction or conditions on desired model and controller structure. The MIMO controller, of order as high as 196, has been successfully reduced and replaced by a MIMO PID.

All the developed controller design techniques have been amply illustrated by application in Load Frequency Control (LFC) and Power System Stabilizer (PSS) design for different power system problems. It is shown that simple, low-order implementable controllers may be designed for robustly stabilizing a power system operating condition of load and line parameter perturbation.

Keywords: Model Matching, Controller design, Reduced order modeling, Load frequency control, Power System stabilizer Optimal, control. Interval System.