

Mudpack

An Interactive Software Package for Investigating the Small-Signal Dynamic Performance of Multi-Machine Power Systems.

(‘Mudpack’ is an acronym for MUltimachine Dynamics PACKage)

This brochure introduces Mudpack which is a comprehensive set of interactive software tools for:

- The conventional analysis of the small-signal stability and damping performance of multi-machine power systems (i.e. eigenanalysis, mode shapes, participation factors, frequency & time response, etc.)
- Designing power system stabilizers (PSSs) and FACTS device stabilizers (FDSs)
- Assessing the relative effectiveness of PSSs and FDSs
- Co-ordinating the design of PSSs and FDSs
- Analysing the performance of Voltage Source Converter based HVDC transmission systems
- Analysing the performance of wind energy conversion systems
- Analysing the performance of modal estimators based on the ambient fluctuations of system variables

Introduction

There is a world-wide trend to increase the utilisation of existing and planned power system plant through increased loading levels and more widespread inter-connection. This trend is being supported by research into and development of



flexible AC transmission system (FACTS) devices and associated controllers. As the loading of power systems increases, small-signal instability and poor damping may emerge as a limiting factor in power system planning and operation [1 chap. 1]. It is therefore becoming increasingly important that system planners have effective tools for accurately modelling the small-signal dynamics of large power systems and for facilitating the coordination of power system controls to enhance system performance.

There is an emphasis in the package on:

- Simple procedures for the tuning of PSSs and FDSs.
- Assessing the relative effectiveness of existing stabilizers installed on both generators and FACTS devices in damping selected modes of oscillation.
- The co-ordinated tuning of stabilizers for both generators and FACTS devices.
- The analysis of the interactions between stabilizing controls.

The basis for analysing the effectiveness and/or co-ordinating decentralized PSSs and FDSs are the damping torques induced on the shafts of generators by the stabilizers. These methods provide clear engineering insight and understanding of the action and relative effectiveness of the stabilizers installed on the system.

An important feature of the package is the extensive range of graphical displays which are provided to enhance the productivity and effectiveness of the user in analysis and design tasks.

Mudpack Applications

Mudpack has been developed for use by both electricity supply utilities and research institutions. Its potential applications include [2]:

- Determining the small disturbance stability limits of a system.
- Assessing
 - if system damping levels are adequate; and
 - the benefits of using special techniques to improve damping, such as the use of stabilisers on generators, on static VAR compensators (SVCs), on HVDC links or on other FACTS devices.
- Robust design of fixed parameter PSSs and FDSs.

- Coordinated tuning of generator PSSs and FACTS device stabilisers (FDSs).
- Evaluating the small disturbance stability benefits of alternative transmission system development plans including interconnections between systems.
- Validating models by comparing the results of small disturbance studies with the results of actual field tests.
- On-line dynamic security assessment.

Mudpack Features

Mudpack's key features include [2,3]:

- An interactive structure which gives the user close control over the sequence of steps which are taken in conducting a study. In addition the user can generate reports and graphical displays to assess the results at each stage of the study.
- A comprehensive browser-based on-line help facility that includes both detailed descriptions of Mudpack's activities and the extensive use of examples and tutorials.
- Flexible data entry and data editing facilities.
- An interface for reading loadflow solution data from a PSS/E¹ loadflow raw data file or from an IEEE Common Data Format file.
- Modelling of power system components including generators, static VAR compensators, HVDC transmission systems, thyristor-controlled series capacitors (TCSCs) and nonlinear loads.
 - Twelve (12) generator models are provided including the small-signal equivalents of the 5th and 6th order models used in the PSS/E transient stability software.
- User specification of the plant controllers (e.g. governors, AVRs, exciters, PSSs) by interconnecting blocks from a library of elementary transfer functions.
- Translation of dynamics model data from PSS/E to Mudpack format by means of the optional *PSSE2Mudpack* utility.

1. PSS/E is the Siemens-PTI. Power System Simulator.

- Utilization of the modularity and sparsity of the power system to increase the speed and reduce the storage requirements of the software.
- Eigenvalue and eigenvector analysis, including the calculation of participation factors and mode shapes.
 - For systems with less than about 2500 state variables, calculation of all the eigenvalues/vectors and participation factors using QR transform methods.
 - Calculation of a few eigenvalues close to user-specified points in the complex-plane using either the Modified Arnoldi Method or Subspace Iteration Method. The eigenvectors and participation factors of the eigenvalues can be calculated if required. These methods are particularly useful for identifying the inter-area modes of large systems for which the QR method is unsuitable, particularly when the number of states exceeds 2500.
 - A variety of facilities to graphically display eigenvalues, right eigenvectors, participation factors and mode shapes is provided.
- Calculation and graphical/tabular display of transfer-function residues. Mudpack's residue analysis tools facilitate the selection of suitable stabilizing signal(s) and the tuning of FDSs.
- Calculation and graphical display of (1) selected frequency responses in Bode form and (2) the damping and synchronising torque components acting on generator rotors. Specialised activities and graphical displays are provided for stabiliser tuning, including activities to disable the shaft dynamics of generators, calculate PVr characteristics [4], inject speed and other test signals, and perform frequency response curve fitting.
- Calculation and graphical display of the contribution of individual PSSs and FDSs to the shifts in selected eigenvalues. This information is displayed in a form which facilitates the coordination of PSSs and FDSs [7,8,9].
- Graphical display facilities for assessing the relative effectiveness of individual PSSs and FDSs in contributing damping to selected modes.
- Analysis of interactions between stabilizers (both PSSs & FDSs)
- Automated co-ordination of stabilizer (both PSSs and FDSs) gains to achieve specified damping criteria.
- Efficient calculation and graphical display of step responses in the time domain.

- Facilities for combining the results of several studies in a single graphical display for convenient comparison (e.g. eigenvalue, frequency- and time-domain plots).
- The state-space model of the power system and various other results produced by Mudpack can be saved in Matlab¹ readable form for research purposes.
- Fully programmable macro facility to facilitate the productive analysis of large numbers of study-cases.

The functional structure of Mudpack is illustrated in Figure 1.

1. Matlab is a trademark of The MathWorks, Inc.

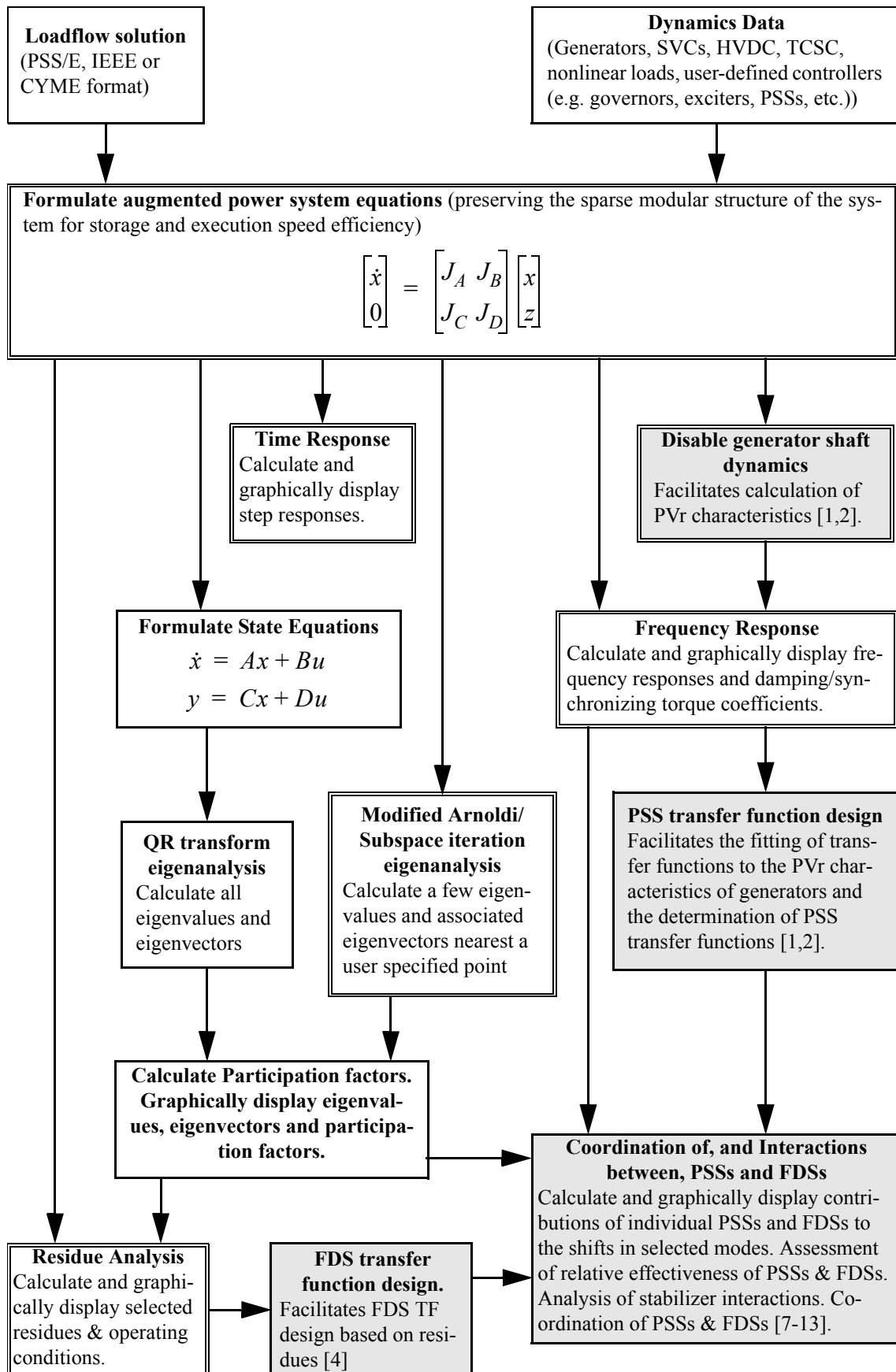


Figure 1: Functional Structure of Mudpack. The shaded elements are associated with the design and co-ordinated tuning of stabilizers (PSSs and/or FDSs). The double-lined elements utilize sparsity.

Obtaining a Demonstration Version of Mudpack

We can provide a demonstration version of Mudpack for a period of three months. This version is limited to systems with less than 50 buses, 200 branches and 10 devices (generators, SVCs etc.) and does not include the selected eigenvalue analysis facilities which are available in the complete version of Mudpack.

The demonstration version includes two tutorial studies with detailed step-by-step instructions.

There is a nominal charge of \$A 150.00 for the demonstration version which will be offset against the cost of a Mudpack licence, should you decide to proceed to purchase Mudpack.

You are requested to send a banker's cheque, for the above amount, payable to:

School of Electrical & Electronic Engineering,
The University of Adelaide,
AUSTRALIA 5005.

We will arrange for you to download the demonstration version from a password-protected web site when we receive your payment.

Contact information is listed at the end of this brochure.

History of Mudpack's Development

The development of Mudpack began over a decade ago at the University of Adelaide to facilitate research into a coordinated approach to the design of power system stabilisers (PSSs) in multi-machine power systems. The approach developed [4,5] was applied to the tuning of PSSs which were installed by the Electricity Trust of South Australia (ETSA) as part of the 1990 interconnection between the South Australian and Victorian/New South Wales power grids [6]. Mudpack was used by The Five-State System Model Task Force to validate the model of the South East Australian power-system, based on system-wide field test results [1, chap. 6]. The package has the capability to model HVDC transmission systems, TCSCs, nonlinear loads and generator saturation. Software has also been developed to implement techniques for quantifying the interactions which occur between stabilisers and generators [7,8,9,10]. Facilities in Mudpack were employed to tune the Power Oscillation Damper (POD) fitted to the Blackwall SVC associated with the interconnection between Queensland and New South Wales. Recently modules have been added to Mudpack for the analysis of:

- The HVDC-Light interconnection, called Murraylink, between South Australia and Victoria;
- Wind Energy Conversion Systems in Tasmania; and
- The Basslink interconnection between Tasmania and Victoria.

Mudpack Users

Mudpack has been acquired by the following commercial organisations:

- (1) ElectraNet SA (formerly ETSA Transmission Corporation),
- (2) Powerlink Queensland,
- (3) VENCORP (formerly the Victorian Power Exchange),
- (4) Hydro Tasmania (formerly Hydro-Electric Corporation, Tasmania),
- (5) National Electricity Market Management Company Limited (NEMMCO).
- (6) TransGrid (formerly Electricity Transmission Authority of New South Wales),
- (7) ABB Utilities, Sweden
- (8) Transend Networks Pty. Ltd.
- (9) ABB Consulting, USA

Computer System Requirements

Mudpack is available on Pentium (or compatible) personal computers running under the Windows 2000/XP operating system.

Purchasing Mudpack

For information on the costs of purchase and maintenance please contact Dr. Mike Gibbard. Contact details are listed at the end of the brochure.

Training Courses

The University is able to provide training in the use of Mudpack, small-signal stability analysis and stabiliser tuning, tailored to your requirements. The University has presented three-day training courses for engineers in Powerlink Queensland, the Hydro Tasmania, VenCorp, ElectraNet SA, NEMMCO and others. The hands-on tutorial exercises were developed to be directly relevant to the small-signal stability interests of the particular organisation concerned.

The cost of training is not included in the purchase price of Mudpack.

Future Developments

The development of Mudpack is ongoing and is currently being supported through a three-year research and development project which is scheduled for completion in December 2007. This project is jointly funded by seven organisations through a research and development agreement with the University's Adelaide Research and Innovation Pty. Ltd.

It is planned to:

- Develop a module to investigate the small-signal dynamic performance of hydro-electric systems;
- Enhance Mudpack's selected eigenvalue analysis facilities in order to identify the least damped modes over a selected frequency range;
- Automate the linearization of non-linear control system models;
- Continue to enhance Mudpack's graphical displays and user interface.

Further Information

For further information please contact:

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