Outlines

POWER SYSTEM STABILITY ANALYSIS (EEEN40340)

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Contents

- Basic stability concepts
- Power flow analysis (numerical stability)
- Voltage stability
- Angle stability
- Frequency stability
- Impact on stability of distributed generation and other devices
- Advanced stability concepts
- Power system software “Dome”

Basic Stability Concepts

- Nonlinear autonomous systems
- Equilibrium points
- Stability regions
- Bifurcation theory

Power Flow Analysis

- Power system model and background
- Equations and solution techniques
- Numerical vs. system stability
- Modal analysis
- Contingency analysis

Voltage Stability

- Definitions
- Basic concepts:
  - Saddle-node bifurcation
  - Limit-induced bifurcation
- Homotopy methods and Continuation Power Flow (CPF)
- Direct methods (based on optimization techniques)
- Indices
- Protections and controls
- Impact of wind generation
- Real case example: August 2003 North American blackout

Angle Stability (I)

- Small-signal stability analysis:

  Definitions

  Hopf Bifurcations

  Control and mitigation

  Practical applications

- Real case example: August 1996 WSCC blackout

Angle Stability (II)

- Transient Stability (large-disturbance):

  Definitions

  Time domain analys

  Direct Methods:

    Lyapunov's function (energy function)

    Equal Area Criterion

- Impact of wind generation
- Impact of energy storage devices
- Real case example: November 1965 Northeast US and Canada clackout
- Real case example: May 1997 Chilean blackout

Frequency Stability

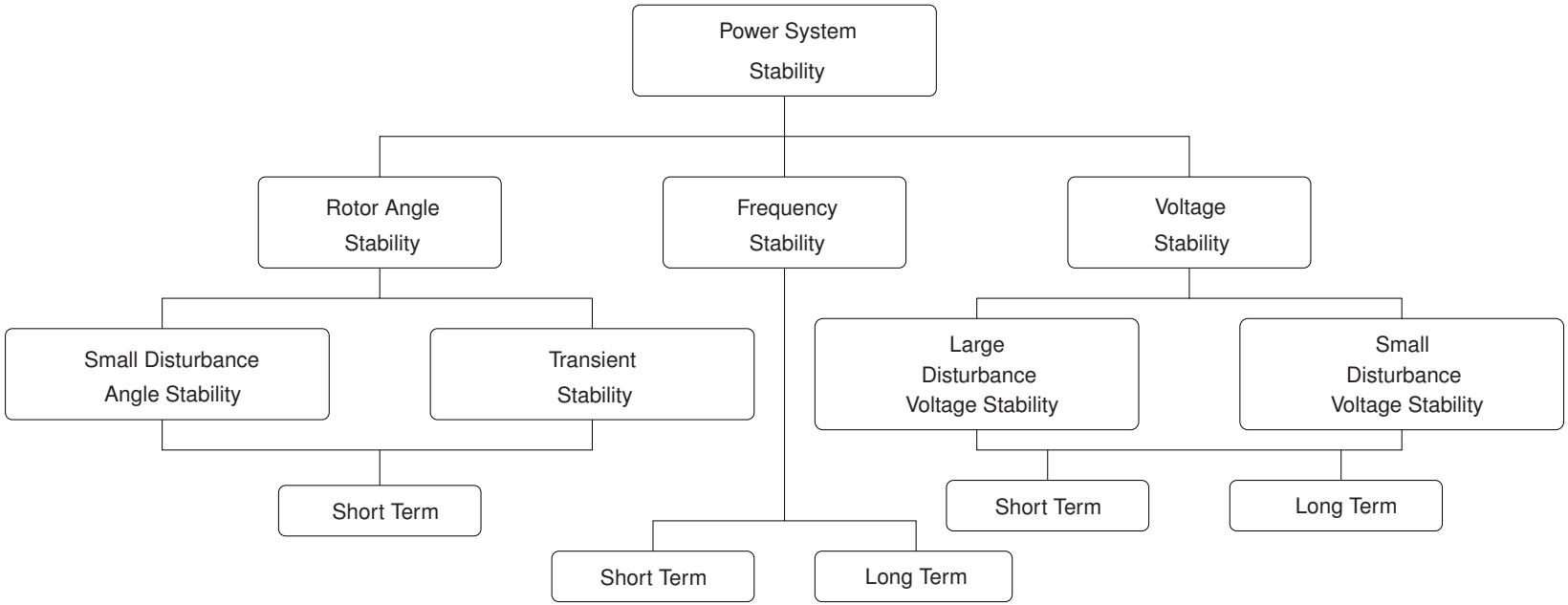
- Definitions
- Basic concepts
- Protections and controls
- Impact of wind generation
- Impact of energy storage devices
- Impact of frequency-controlled loads
- Real case example: September 2003 Italian blackout
- Real case example: November 2006 European blackout

Advanced Stability Concepts

- Fundamental matrix solution
- Monodromy matrix and Floquet's multipliers
- Limit cycles and routes to chaos
- Spectral analysis and Lyapunov exponents
- Stability of non-autonomous systems
- Hybrid-systems (both continuous and discrete variables)
- Impact of delays on power system stability
- Impact of stochastic processes on power system stability

Taxonomy of Power System Stability Phenomena

- IEEE-CIGRE classification (IEEE/CIGRE Joint Task Force on Stability) Terms and Definitions, “Definitions and Classification of Power System Stability”, *IEEE Trans. Power Systems and CIGRE Technical Brochure 231*, 2003:



Introductory Lab Activities

- For those that are not familiar with the software tool “Dome”, there will be two introductory labs (4 hours):
- This introduction will cover:
  - Linux shell basic commands
  - SSH and SFTP from Windows to Linux
  - Basic usage of Dome

- Introductory labs are scheduled on February 1st and February 8th from 11:00 to 13:00
- Those who have attended the “Power System Control” module can skip these labs

Laboratory Activities

- 1st Lab : Power flow analysis and numerical stability
- 2nd Lab : Continuation power flow analysis and N-1 contingency criterion
- 3rd Lab : Small-signal stability analysis and and extended CPF analysis
- 4th Lab : Transient stability analysis and determination of the critical clearing time
- 5th Lab : Frequency stability analysis and effect of frequency controlled loads and storage devices

Lab Schedule

- 1st Lab : February 15th
- 2nd Lab : February 29th
- 3rd Lab : March 28th
- 4th Lab : April 11th
- 5th Lab : April 15th

Presentation on a Country-wide Blackout

- A group presentation has to be prepared on a major blackout.
- The report has to clearly state and discuss the causes (e.g., kind of instability) of the blackout, a brief summary of the sequence of events, and possible remedial actions to prevent the blackout.
- Each group will be composed of two or three students.
- A list of major blackouts is available on the module webpage.
- The presentations (max. 15 minutes each) on the blackout will hold on the 25th of April (last lecture of the module).

Evaluation

- Final Exam (30%)
- Reports on laboratory activities (60%)
- Presentation on power system blackout (10%)
- Important remarks on lab reports:
  1. Report has to be prepared **individually** (**NOT** in group) for each lab activity. Reports prepared in group will be graded G-.
  2. Lab-based reports have to be submitted within **10 days** after the lab activity. One grade will be taken out per each day of delay.

Questionnaire

- The laboratory activities are part of a long term project on didactic innovation
- The students are invited to fulfill and submit a questionnaire on lab activities
- The questionnaire can help improve future lab activities!

Bibliography (Power Systems)

- P. Kundur, *Power System Stability and Control*, Mc Graw Hill, 1994.
- C. A. Cañizares, Editor, *Voltage stability assessment: concepts, practices and tools*, IEEE-PES Power System Stability Subcommittee Special Publication, SP101PSS, May 2003.
- M. Ilić and J. Zaborszky, *Dynamics and Control of Large Electric Power Systems*, Wiley, New York, 2000.
- EirGrid & Soni, *All Island TSO Facilitation of Renewables Studies*, 2012. Available at www.eirgrid.com/media/FacilitationRenewablesFinalStudyReport.pdf
- Journal papers and technical reports.
- Module slides available on line.

Bibliography (Stability Analysis)

- J. Stoer and R. Bulirsch, *Introduction to Numerical Analysis*, Second Edition, Springer-Verlag, 1993.
- R. Seidel, *Practical Bifurcation and Stability Analysis*, Springer-Verlag, New York, 1994.
- Journal papers and technical reports.
- Module slides available on line.

Links

- Web page of the course:

  http://faraday1.ucd.ie/stability.html

- Web page of the software tool:

  http://faraday1.ucd.ie/dome.html

- Blackboard:

  https://elearning.ucd.ie