Workshop

"Increased Utilisation of the Nordic Power Transmission System"

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Determination of stability limits - Angle stability -

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Definitions and description

- *Power system stability has to do with the ability of a power system to maintain it's steady state balance during normal operation and to return to an acceptable steady state situation after being exposed to disturbance(s).*
- Steady state stability has to do with the analysis of the electromechanical oscillations of the system for a given state of operation (*small-signal stability analysis, damping, etc*.)
- Transient stability is defined as the ability of the power system and the individual generators to maintain synchronism after an operational disturbance.

The system is within the stability limit when, after some given fault situations, it is able to return to an acceptable steady state situation.

Determination of stability limits
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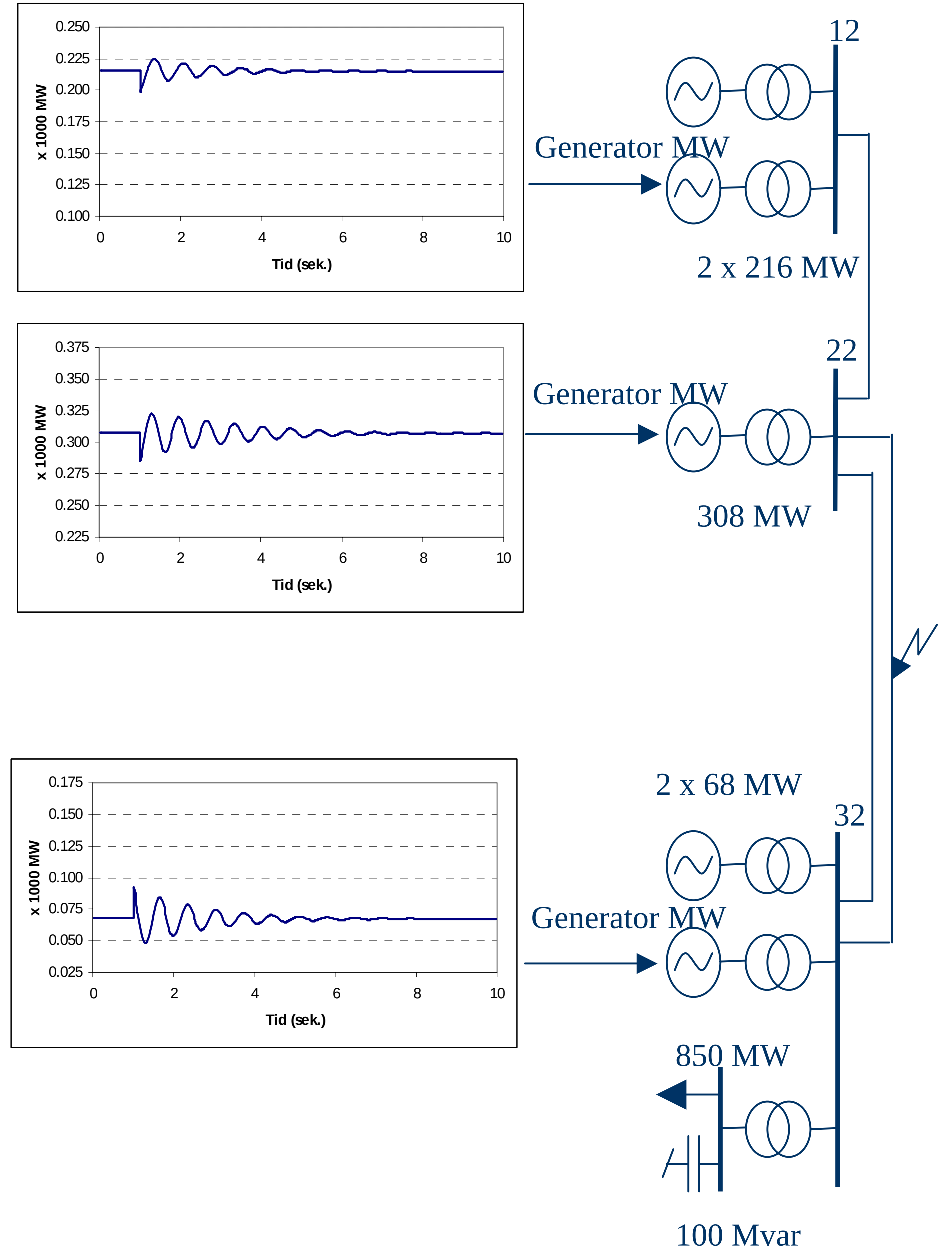
<u>Steady state stability:</u>

An example illustrating power oscillations between areas.

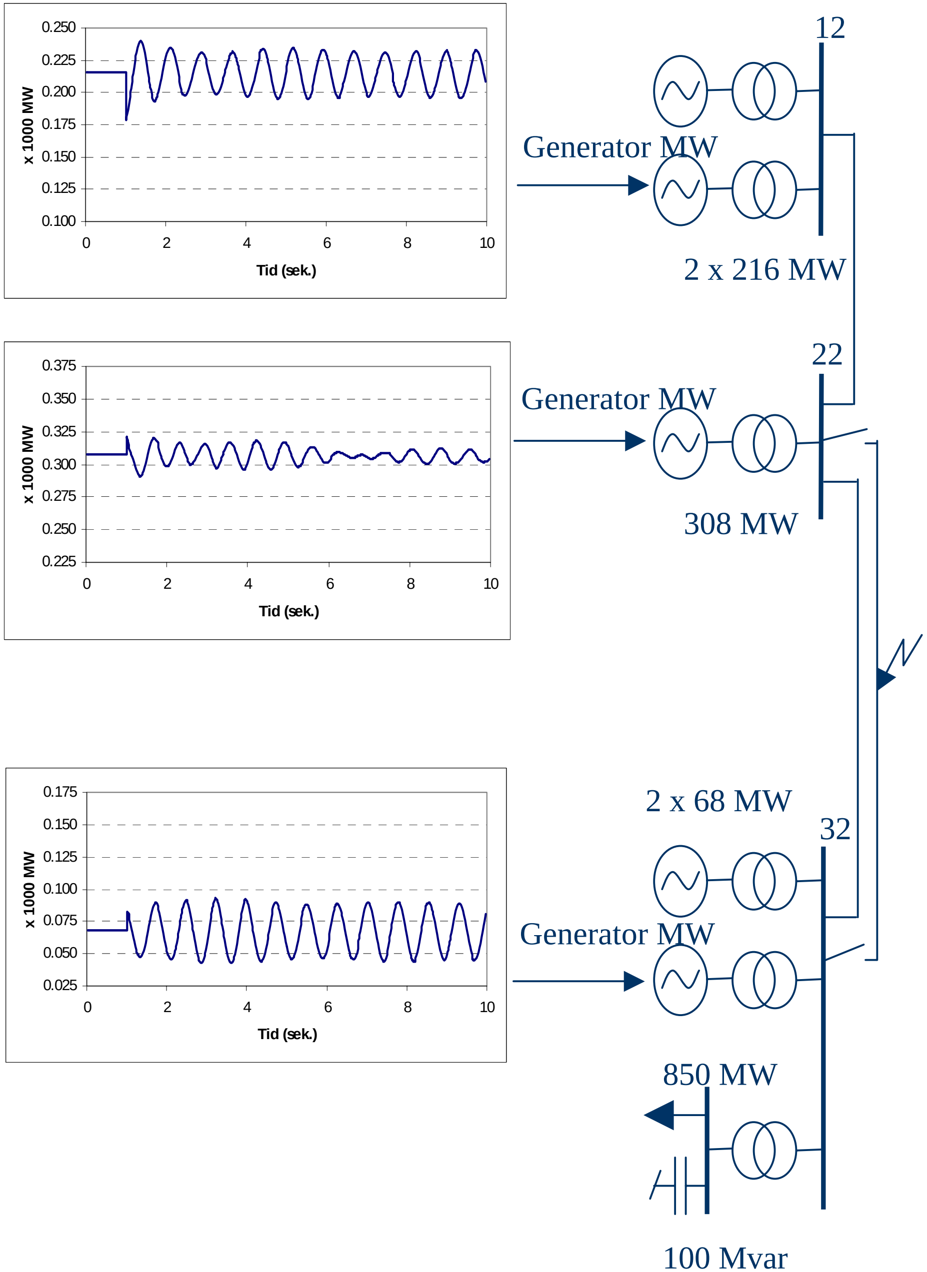
Acceptable damping and a stable system



Steady state stability:

An example illustrating power oscillations between areas at a weakened grid.

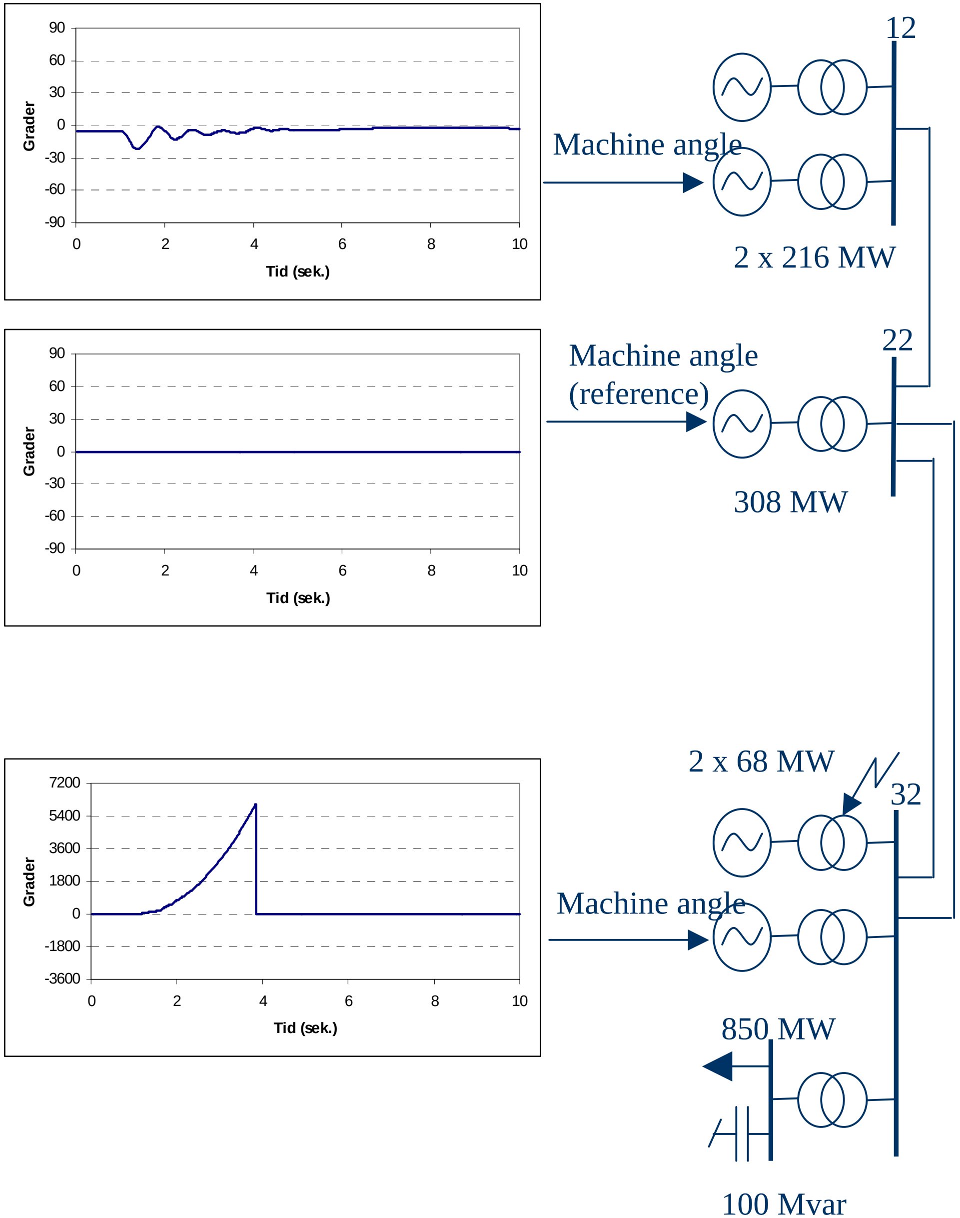
Undamped power oscillations – unstable system



Transient stability:

An example illustrating transient instability after a fault.

Observation of relative machine angles identifies lack of synchronising torque



Proposed approach for determination of stability limits

- Practical definition:

  The system is within the stability limit when, after some given fault situations, it is able to return to an acceptable steady state situation.

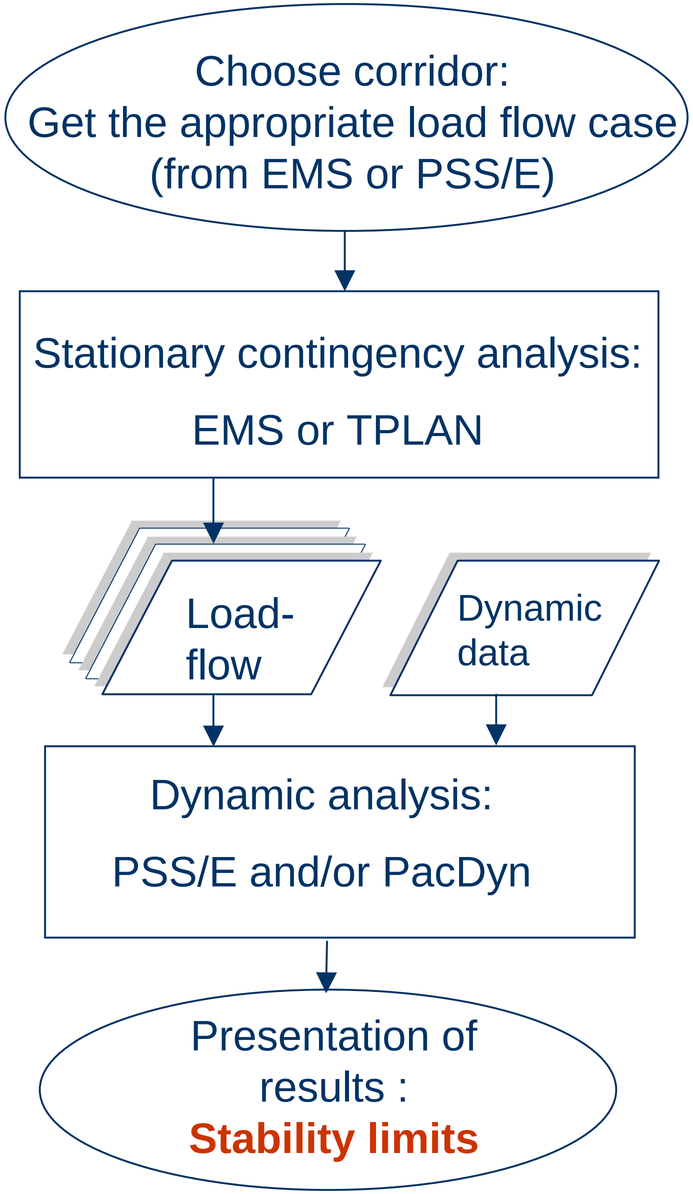
- Key questions:
  - What are the *dimensioning fault situations*?
  - What are the characteristics of an *acceptable steady state situation*?

Approach for determination of stability limits – Procedures, definitions, criteria and choices

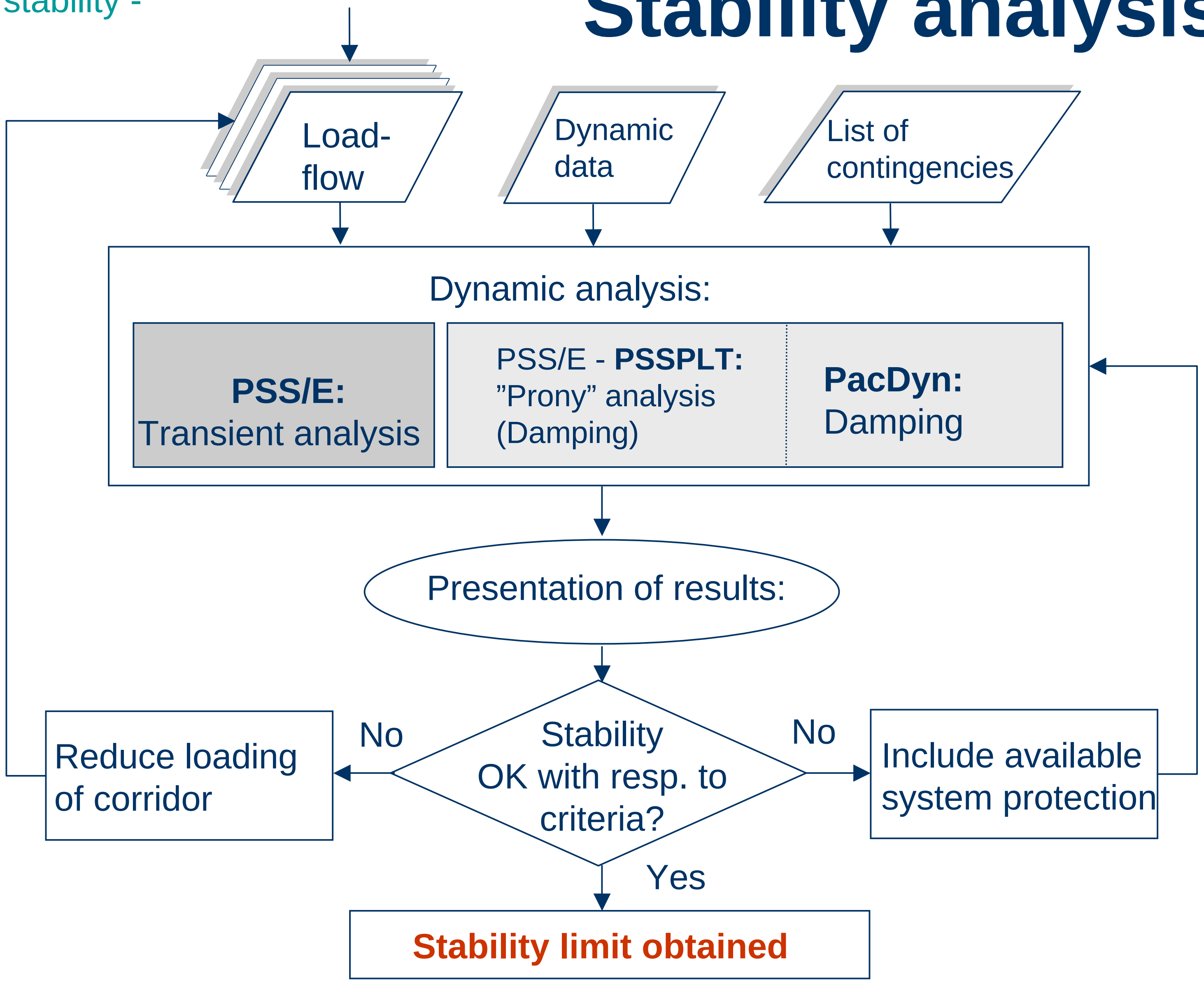
- Procedure for loading up the transmission corridor (i.e. what generators/loads are to be regulated to influence the load flow).
- Critical contingencies to be evaluated.
- Available (and applicable) system protection.
- Criteria:
  - What is an *acceptable damping*?
  - What is a *dimensioning fault sequence for transient stability*?
- Clear and precise presentation of results, providing simplified interpretation of the analyses.

Ordinate procedure

- Steady state analysis:
  - Purpose: To find a steady state load limit as a starting point for the stability analysis.
  - Result: Steady state load limit and load flow files representing different loading of the corridor.
- Dynamic analysis:
  - Determines acceptable load flow limit with respect to :
    - Damping
    - Transient stability
    - (Voltage stability)



Stability analysis



Tools and methods for analyses

Steady state stability:

- PacDyn:
  - Modalanalysis (eigenvalues and -vectors, ”modeshapes”)
  - Identification of critical eigenvalues points out relative damping.

- PSS/E:
  - Analysis of simulation results by applying ”Prony” methods points out critical modes and their ”eigenvalues”

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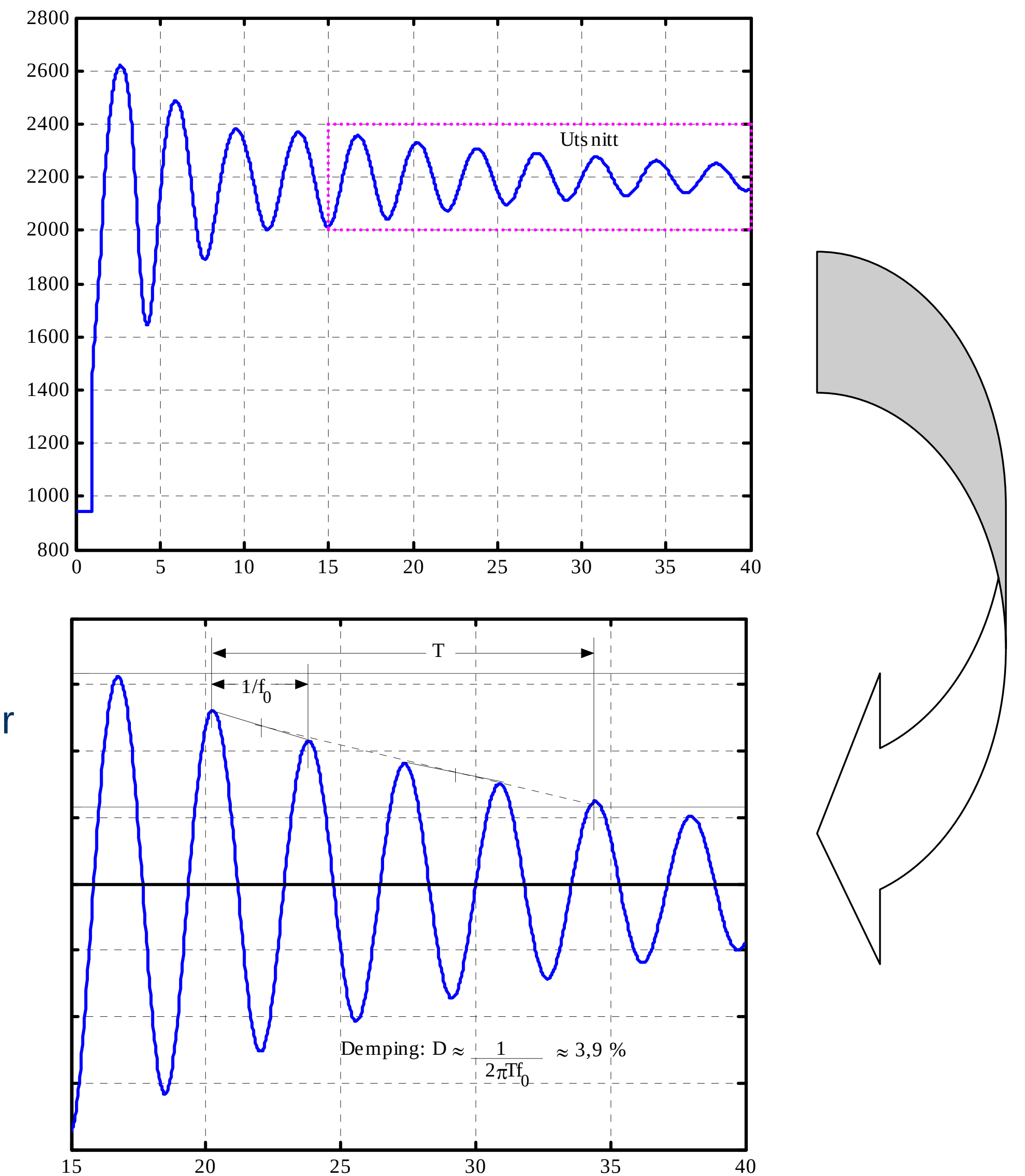
Relative damping:

- Determined from the most critical eigenvalue (lowest damping)
- Relative damping is the ratio between the eigenvalue's real part and absolute value
- Can be estimated from power oscillation trajectories following transients.
- Can also be analysed by applying the "Prony"-method in PSSPLT (PSS/E).



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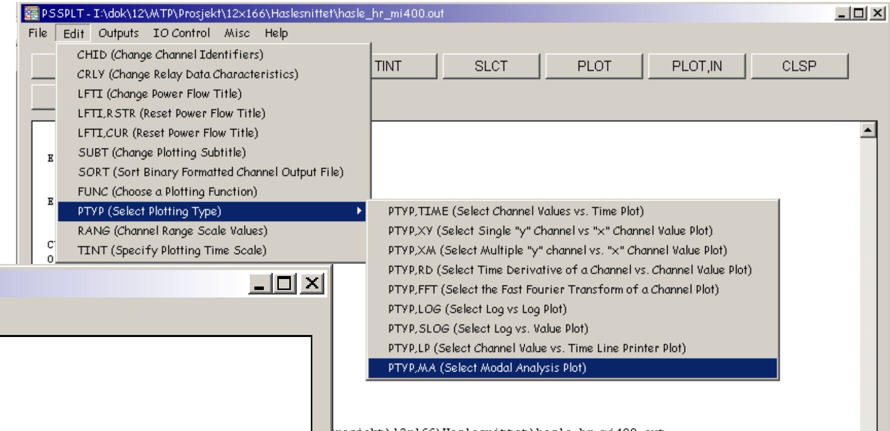
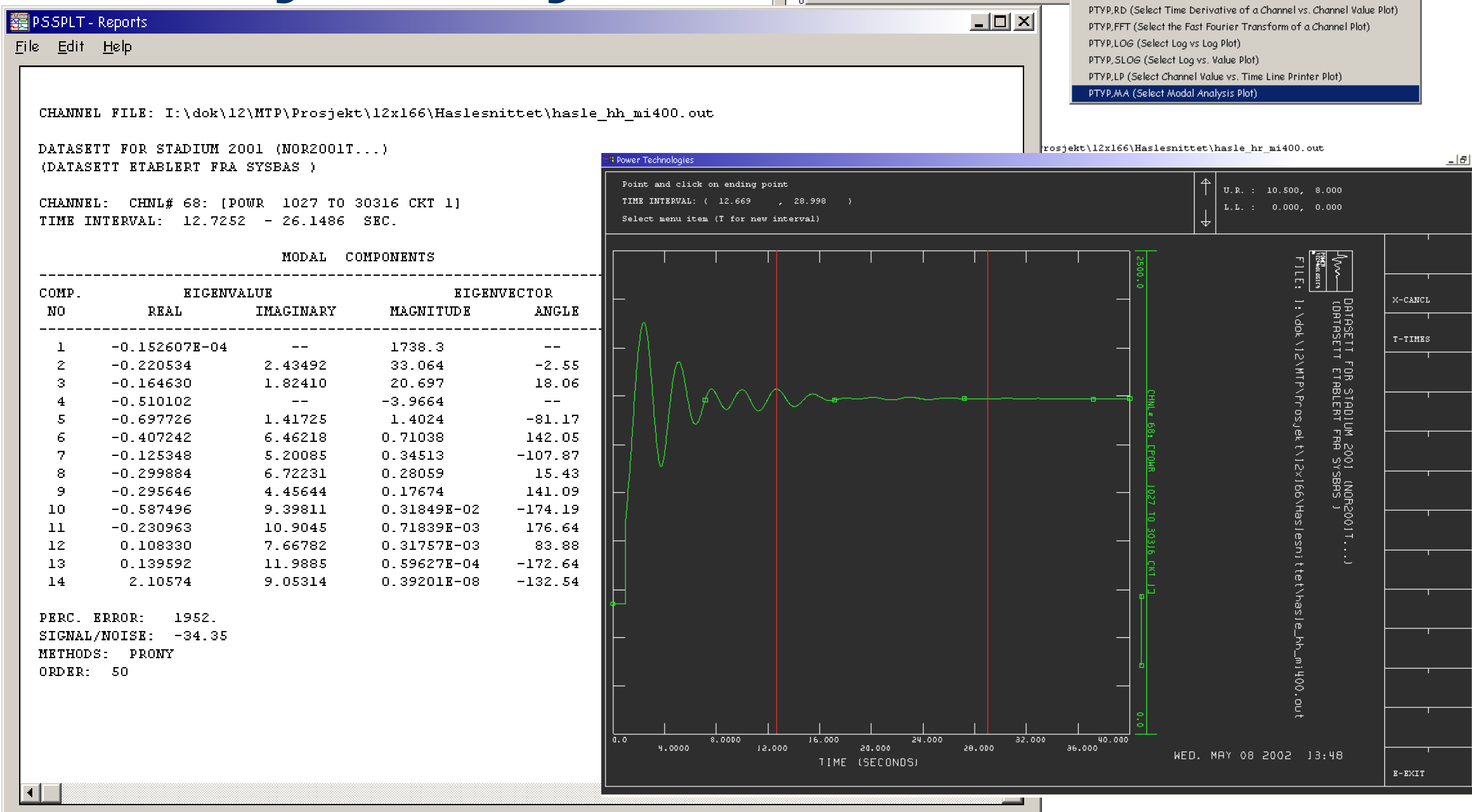
PSSPLT
”Prony” analysis





Tools and methods for analyses

Transient stability:

- PSS/E: Simulation of critical fault sequences (three-phase symmetrical short-circuit followed by a fault clearance and tripping of faulted line or (another) component).
- Purpose: Find the critical clearing time (CCT)
- CCT used as a criteria for setting of load limit

Chosen criteria

- Steady state stability (damping):
  - Relative damping of the critical system mode > 3%
- Transient stability:
  - Critical clearing time for dimensioning fault > 100 – 200 msec.

Example: The Hasle-corridor

- The example illustrates the application of the proposed procedure for determining the stability limits.
- Initial conditions: Heavy-load situation with 2000 MW export through the Hasle-corridor (i.e. from Norway to Sweden).
- Goal: To find limits of steady state as well as transient stability by applying different choices of system protection.