

# Eigenvalue Analysis

## Rapid Analysis of Information of Power System Oscillation Behavior

### At a glance

Stability problems such as inter-area oscillations have become increasingly common in large inter-connected power systems. PSS<sup>TM</sup>E Version 31 integrated the "NEVA – Eigenvalue and Modal Analysis" module extends PSS<sup>TM</sup>E's analytical methods to examine these oscillations.

The NEVA Eigenvalue Analysis module:

- Provides methods to investigate long-term stability
- Allows a deeper view into eigenvectors
- Determines the best damping locations
- Allows evaluation of damping strategies

### The challenge

Power systems are steadily growing with ever larger installed capacity. Formerly separated systems are now interconnected with each other. Modern power systems have evolved into systems with a very large size, stretching out over hundreds and thousands of kilometers. With growing generation capacity, different areas in a power system grow with the effect of adding ever larger inertias.

Furthermore, the unbundling of generation, transmission and supply is less oriented towards the physical nature of the synchronously interconnected power systems, which span a large area and share interactions among the different sub-networks and power plants. However, in the market-driven environment with potentially higher transmission system loading, the operators may be forced to operate the system closer to its stability limits.

As a consequence of these factors, the small signal stability performance of large inter-connected power systems has gained in importance. Inter-area oscillation has been found to be a common problem in large power systems worldwide. Many electric systems have experienced poorly-damped low frequency (0.2-0.8 Hz) inter-area oscillations as a result of system growth and interconnection.

### Our solution

With PSS<sup>TM</sup>E Version 31 a new module "NEVA – Eigenvalue and Modal Analysis" has been introduced, extending the previously used Linear System Analysis PSS<sup>TM</sup>E module, to examine the electromechanical behavior of the power system. The full NEVA version will be available in PSS<sup>TM</sup>E version 31+. In version 31 we offer a reduced version: max. 1500 nodes, max. 200 machines, only PSS<sup>TM</sup>E standard models, models drawn by GMB.

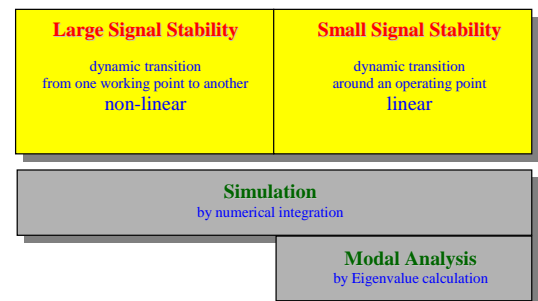


Figure 1: Analysis of electromechanical phenomena

Eigenvalue and modal analysis describe the small signal behavior of the system - the behavior linearized around one operating point - and do not take into account the non-linear behavior of, for instance, controllers during large perturbations. Therefore, time domain simulation and modal analysis in the frequency domain complement each other in the analysis of power systems.

Eigenvalue analysis investigates the dynamic behavior of a power system under different characteristic frequencies ("modes"). In a power system, it is required that all modes be stable. Moreover, it is desired that all electromechanical oscillations be damped out as quickly as possible. The results of an eigenvalue analysis are given as frequency and relative damping for each oscillatory mode.

## PTI – Software Solutions

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A damping ratio of 5 % means that in 3 oscillation periods the amplitude is damped to about 32 % of its initial value. However, the minimum acceptable level of damping is not clearly known. A damping ratio of less than 3 % must be accepted with caution. Damping is considered adequate if all electromechanical modes have a predicted damping ratio of at least 5 %. Figure 2 depicts how the damping of a system can be easily analyzed.

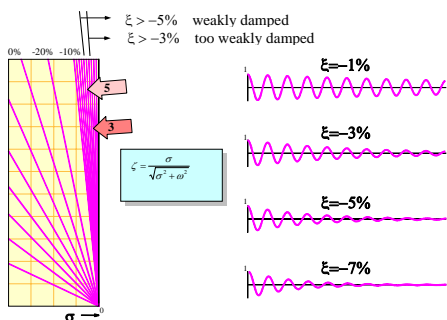


Figure 2: Criteria of weakly and well-damped system

The modal system analysis in NEVA allows a much deeper analysis by not only interpreting the eigenvalues but by also analyzing the eigenvectors of a system. The latter are automatically calculated during the NEVA modal analysis:

- The right eigenvector gives information about the observability of oscillation
- The left eigenvector gives information about the controllability
- The combination of the right and left eigenvectors (residues) indicates the location of controllers

The damping of inter-area oscillations is very important. The oscillations can be damped when extra energy is injected into the system, which instantaneously decelerates the system, and/or vice-versa when extra energy is consumed in the system.

In real power systems the damping energy is obtained from the modulation of load or generation for some period of time, typically in the range of five to ten seconds. The damping energy must have the correct phase shift relative to the accelerated / decelerated systems. Incorrect phase angles

can even excite power oscillations. Figure 3 shows different strategies to damp power oscillations.

Using the system eigenvectors (Figure 4), the best damping location can be found. Depending on the selected damping strategy the residues chart shows the location(s) for, in the example, a PSS (Power System Stabilizer). In this example, other devices that were studied for comparison include an SVC (Static Var Compensator), and a TCSC (thyristor-controlled static compensator).

### Application example

Figure 5 shows a screenshot from the PSS<sup>TM</sup>E NEVA module: The results of an eigenvalue calculation / modal analysis for a 0.3 Hz inter-area oscillation in the SAPP (South African Power Pool).

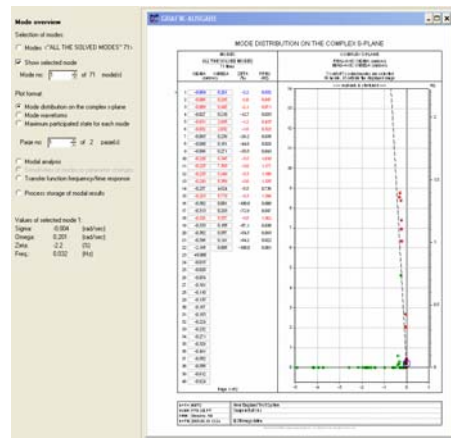


Figure 5: Results of the NEVA eigenvalue analysis

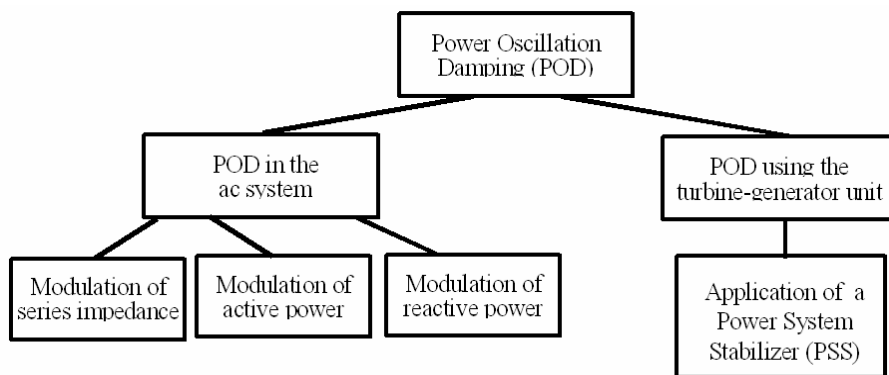


Figure 3: Strategies to damp power oscillations

Figure 4: Eigenvectors of an inter-area mode

