

# **An advanced frequency-domain code for Boiling Water Reactor (BWR) stability analysis and design**

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Nuclear power plants (NPP) provide about 40% of the electricity in Switzerland; from the economic and energy policy points of view, they are very important for the country. This implies the necessity to keep them operating at high efficiency and improve the design of future NPPs.

Stability of BWRs towards combined thermal-hydraulic/neutronic instabilities is an important issue. LKT has been developing a frequency domain code based on state-of-the-art approaches within the framework of an EU project (Natural Circulation and Stability Performance, NACUSP). The product is intended for the stability analysis of present BWRs and the design of the next generation of the NPPs based on natural circulation.

The local power generation in the core of a nuclear reactor is directly related to the neutron flux. It depends strongly on the void (steam) fraction of the coolant via the nuclear reactivity feedback. Void oscillations in the core induce power oscillations due to this neutronic feedback. The power oscillations are intimately coupled to oscillations of all the other flow variables. Stability analysis centers on the determination of the operating region where such power-void-flow oscillations may appear and the response of the reactor at these points. The power oscillations may be *global* (in phase) or *regional* (out of phase). This depends on how many harmonics (modes) of the power distribution are involved in the process.

In order to detect both kinds of power oscillations, the frequency domain code under development includes very sophisticated 3D neutronics based on the Nodal Modal method with the possibility to compute an unlimited number of harmonics. This leads to a large, sparse-matrix, generalized Eigenvalue problem, which is solved by the Arnoldi method. Another important feature of the code is powerful thermal hydraulics, capable of handling non-homogeneous, non-thermal equilibrium and flashing coolant conditions using the local properties of water and steam. Finally, the dynamics of the fuel rods are obtained by the analytical solution of the radial conduction equation in the rod: pellet, gap, and cladding.

The stability analysis needs the steady-state of the reactor at a given operating point. The code first computes this steady-state and then the transfer functions of the various reactor components. This results in large, sparse matrices, which are combined via very complex algebra to obtain reactor transfer functions (for each mode of interest).

Finally, the stability analysis consists in studying the behavior of the reactor transfer functions, their resonance frequency and their stability index. These studies can be done for all the harmonics of the power distribution to find their respective impacts on the response of the reactor system.