Nonlinear Vibrations of Aerospace Structures

University of Liège, Belgium

T07 Bifurcations

Continuation Parameters

Bifurcation Analysis

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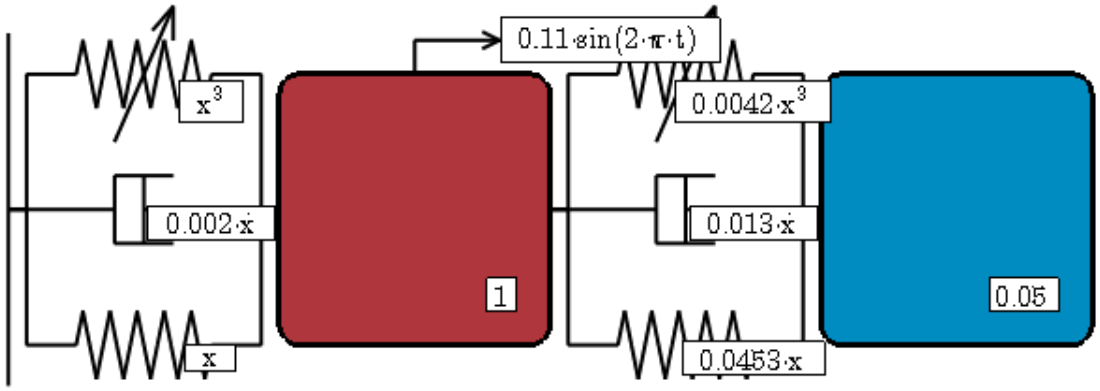
Objectives of This Tutorial

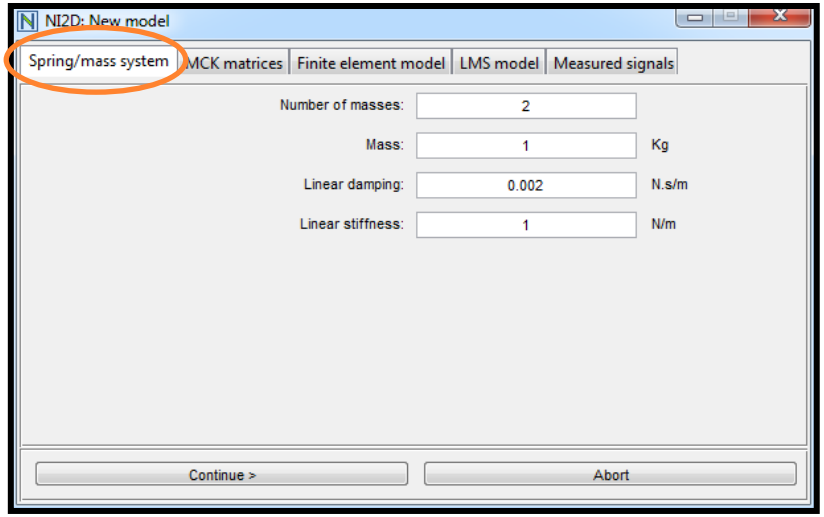
Get familiar with NI2D tools for numerical continuation and bifurcation analysis:

- Understand the influence of continuation parameters.
- Detect and analyze bifurcations.

Case Study: 2-DOF System With Cubic Nonlinearities

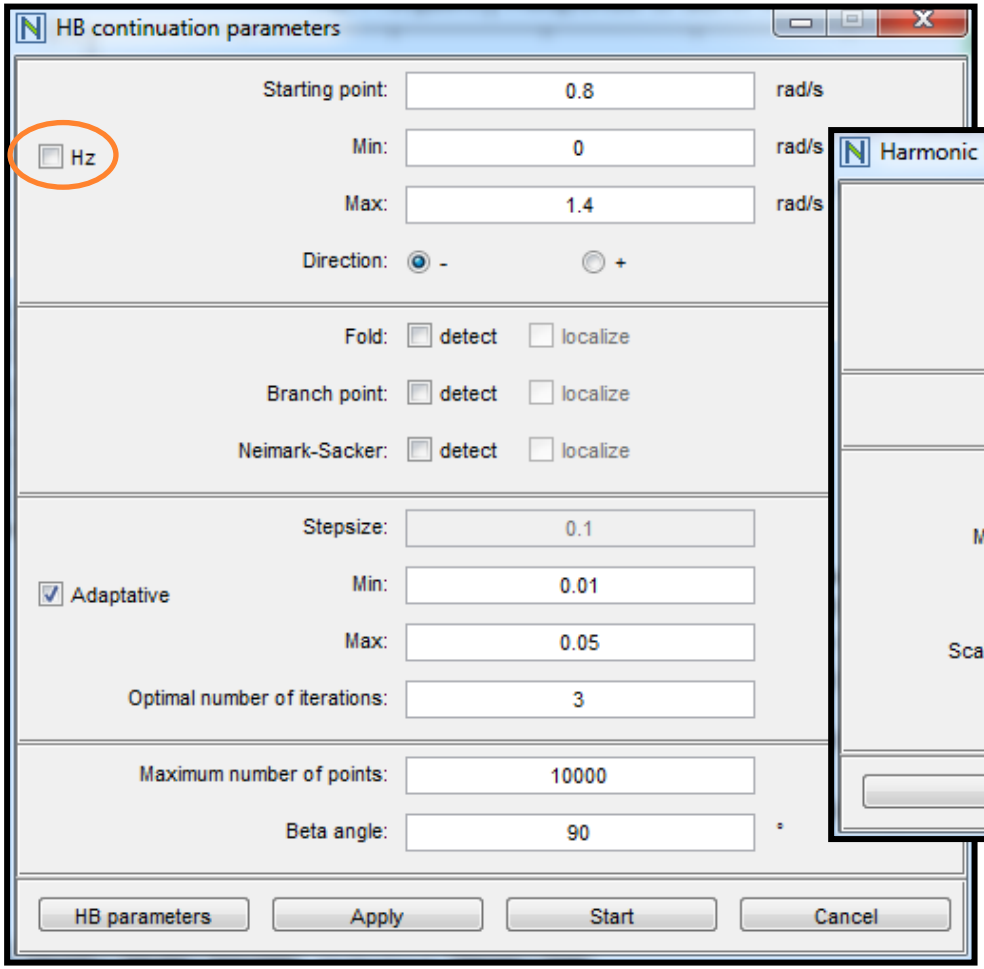
- Create the following 2-DOF system and name it "*2DOF_cubic*".

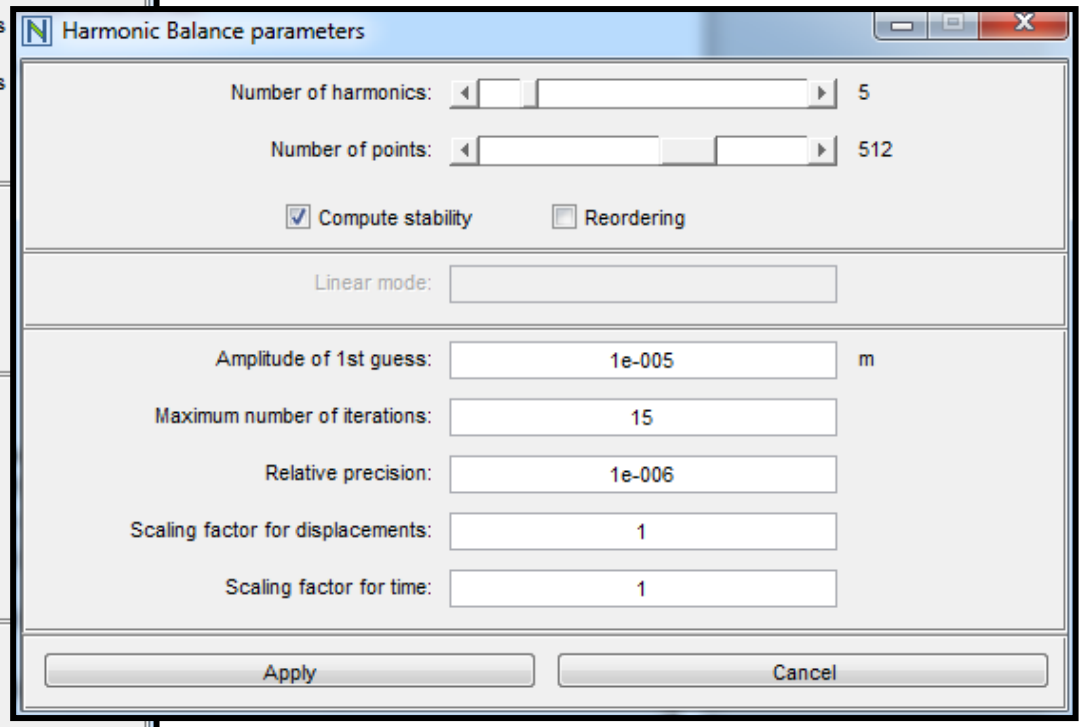




Influence of the Continuation Parameters

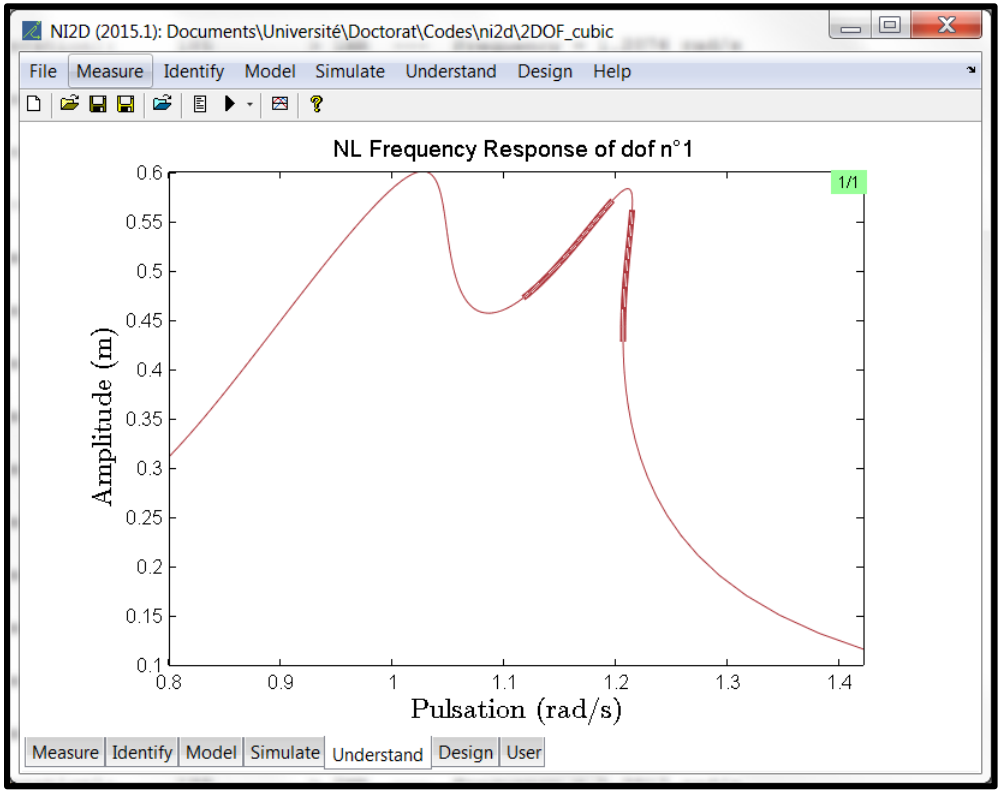
- Select the following parameters.





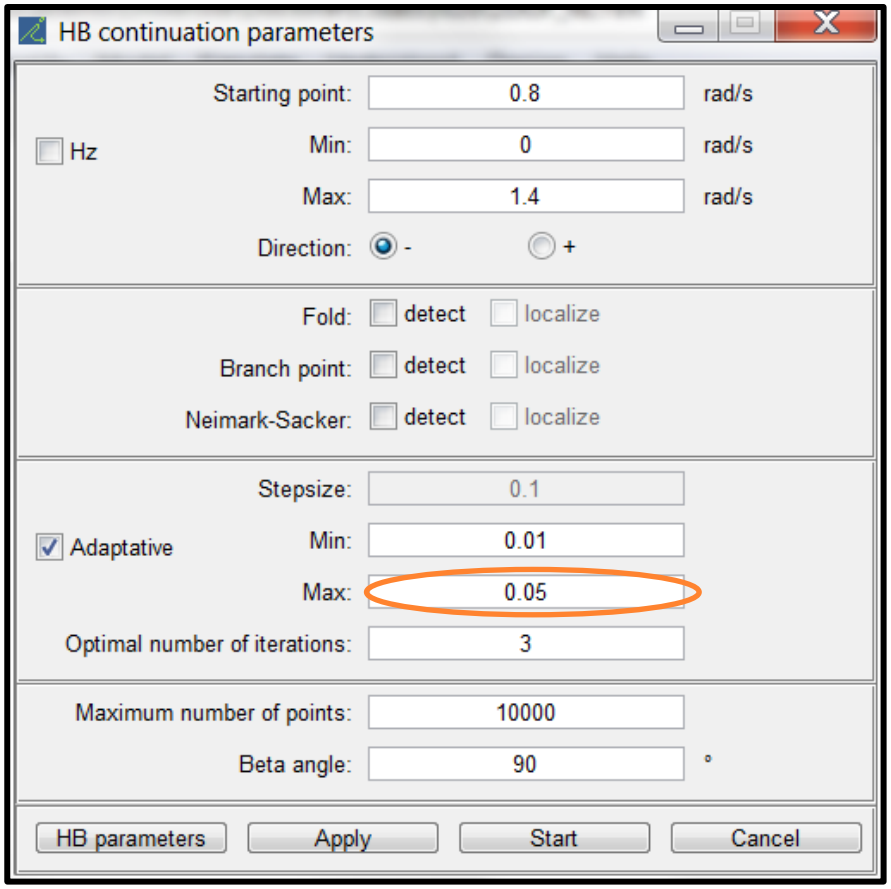
Influence of the Continuation Parameters

- Start the continuation.



Influence of the Continuation Parameters

- Play with the maximum stepsize parameter and analyze its influence on the frequency response.



Try 0.05, 0.1, 1, etc.

Influence of the Continuation Parameters

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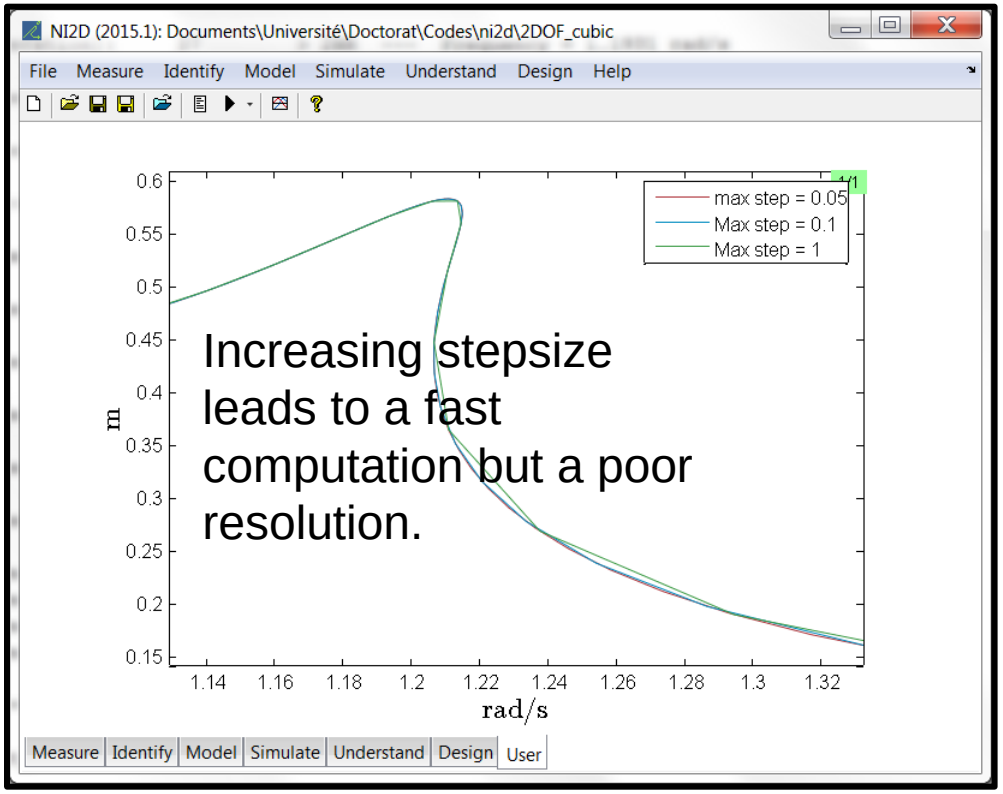
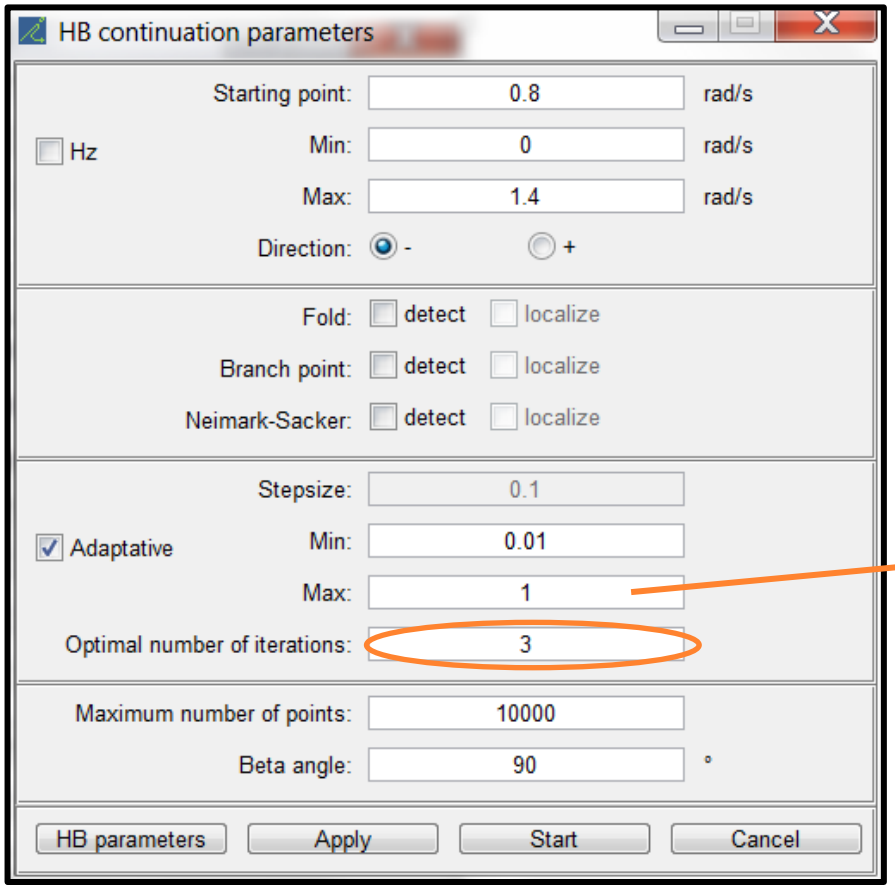


Influence of the Continuation Parameters

- Play with the optimal number of iterations parameter and analyze its influence on the frequency response.

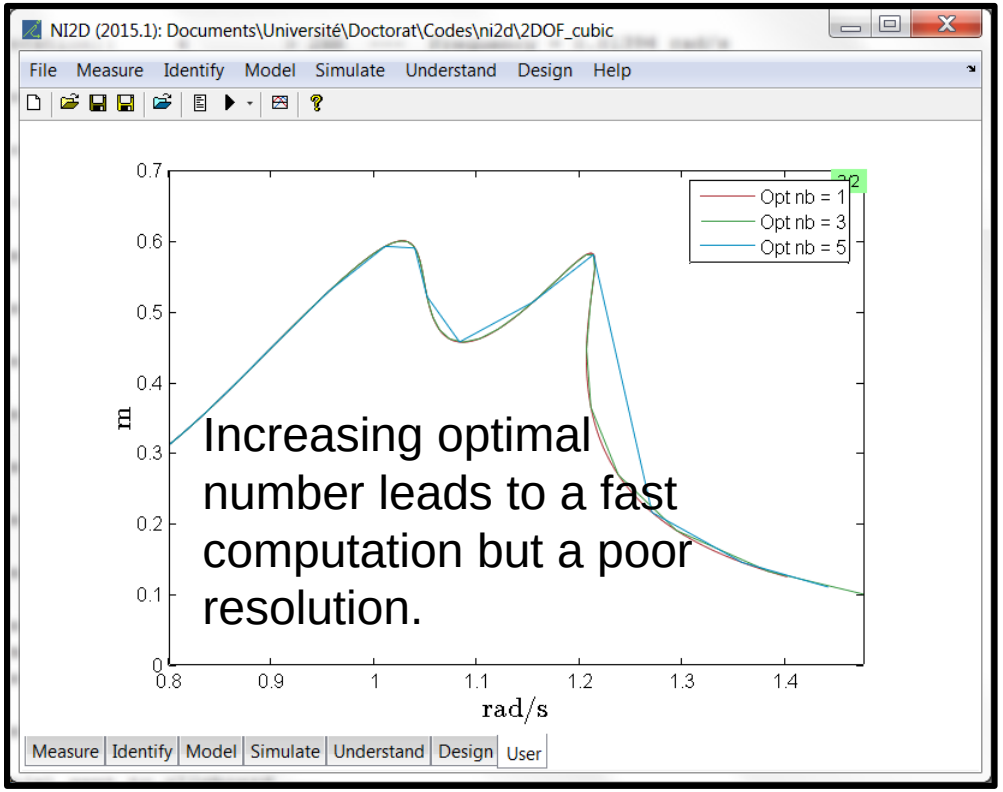


Set max. stepsize equal to 1.

Try 1, 3, 5, etc.

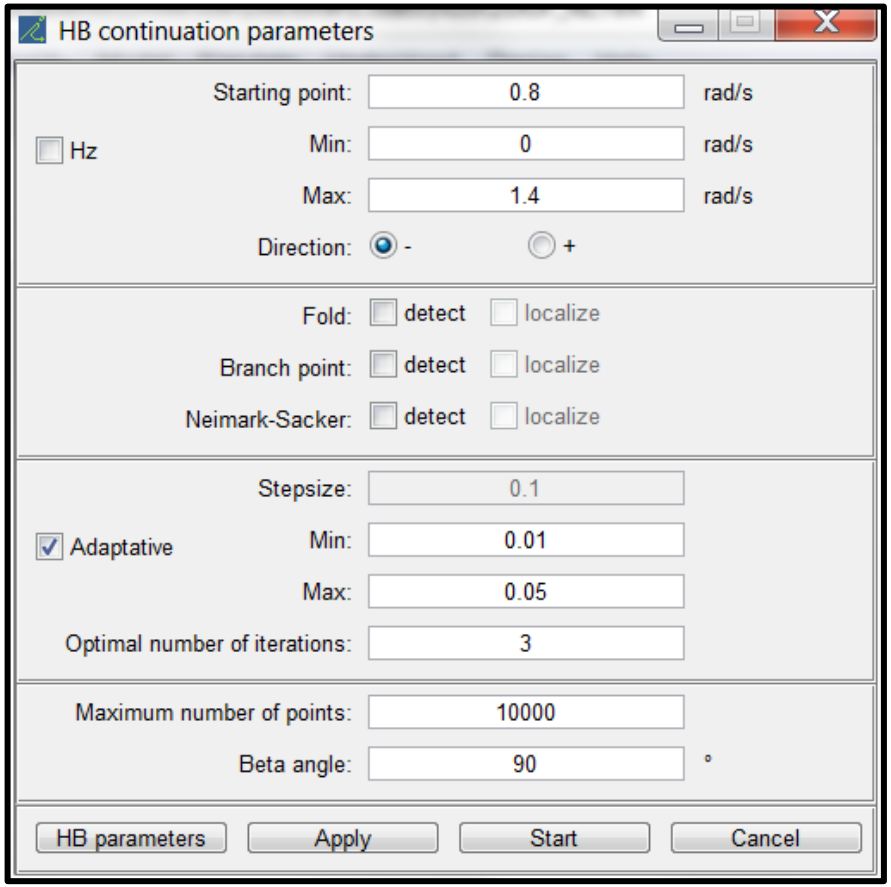
Influence of the Continuation Parameters

- Play with the optimal number of iterations parameter and analyze its influence on the frequency response.

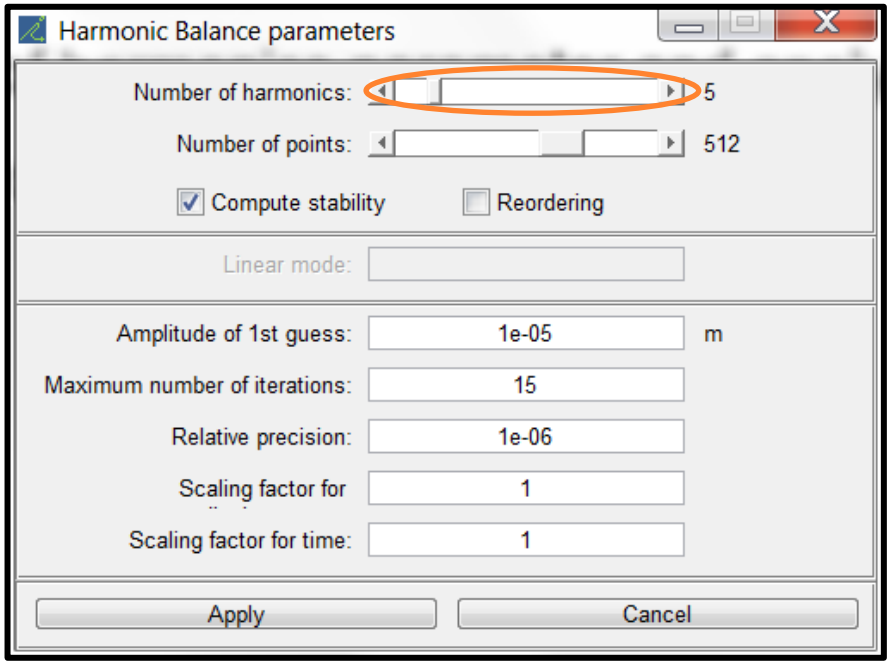


Influence of the Continuation Parameters

- Play with the number of harmonics parameter and analyze its influence on the frequency response.



Try 1, 3, 5, etc.



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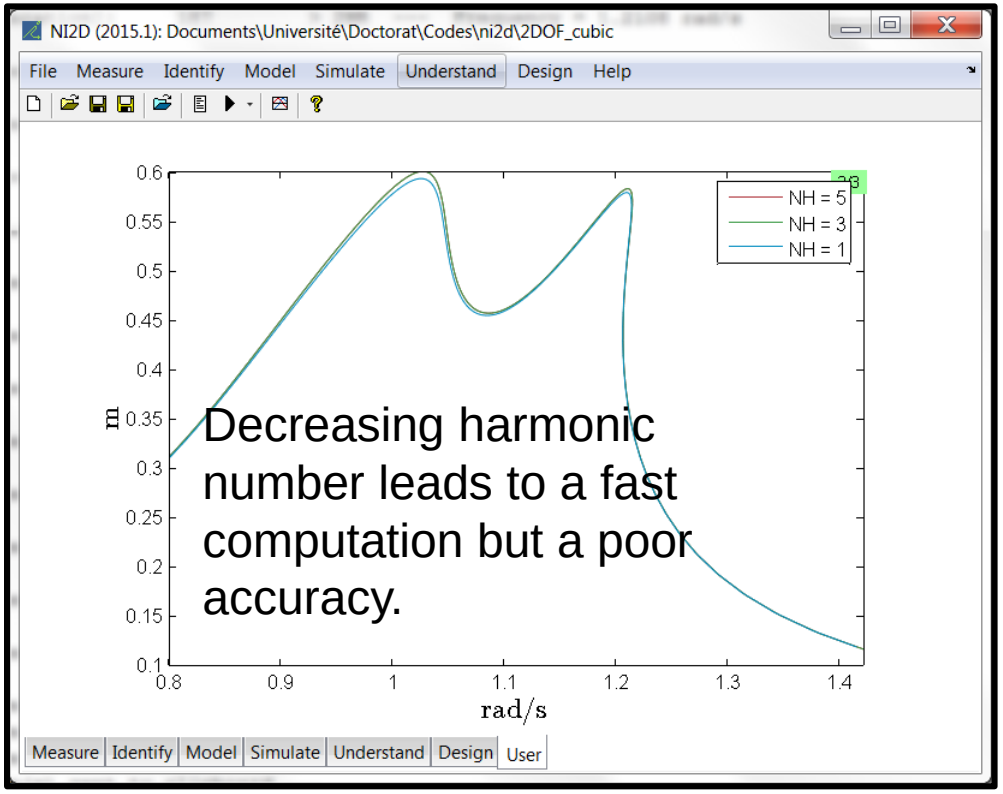
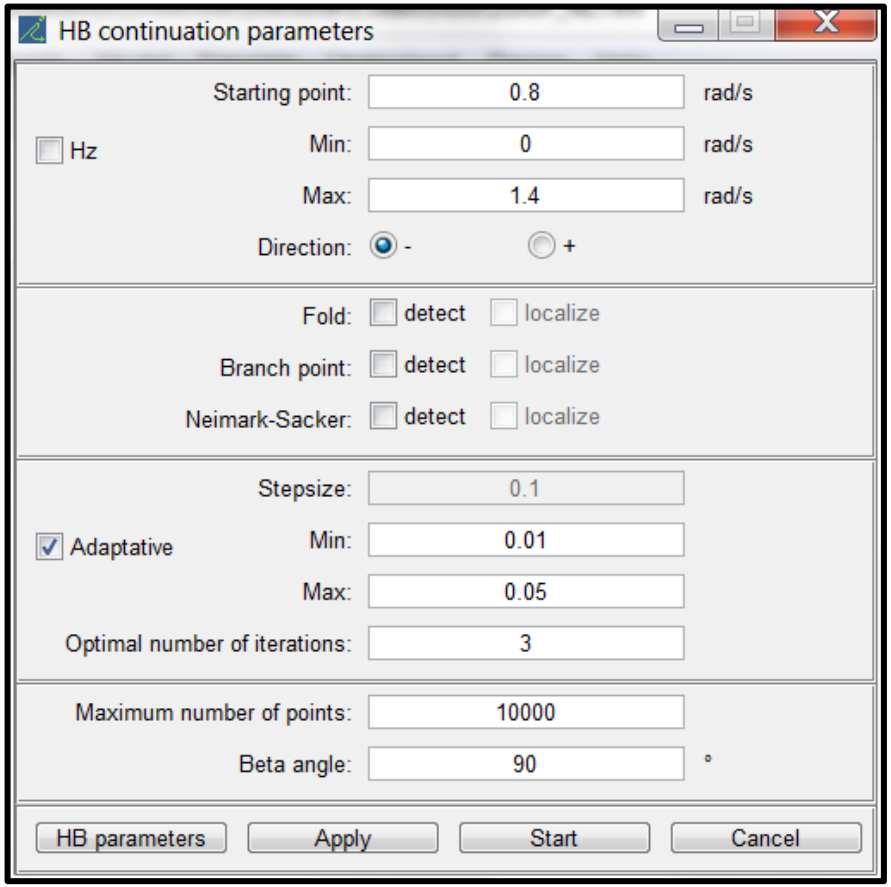
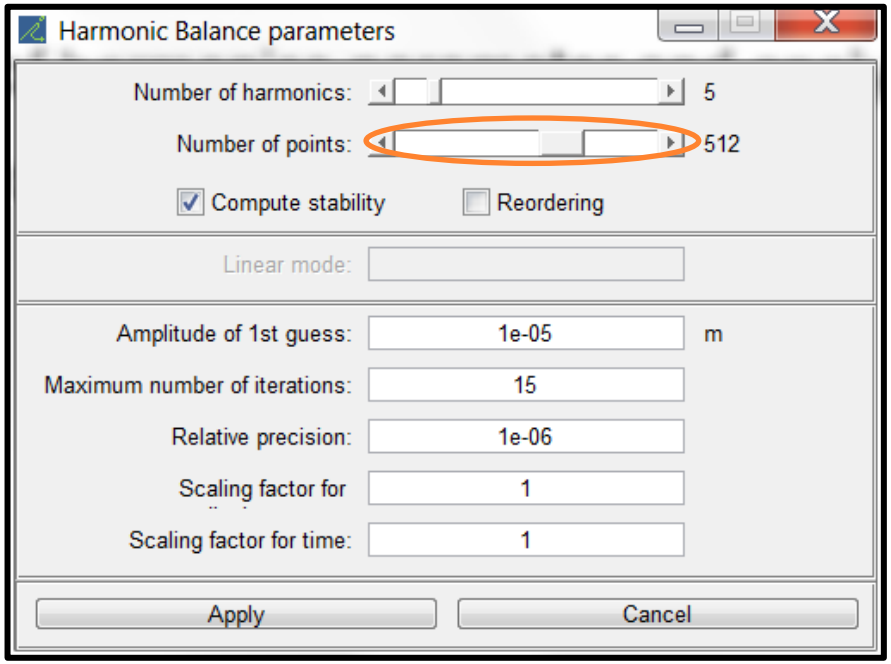


Influence of the Continuation Parameters

- Play with the number of time samples parameter and analyze its influence on the frequency response.



Try 32, 64, 256, etc.



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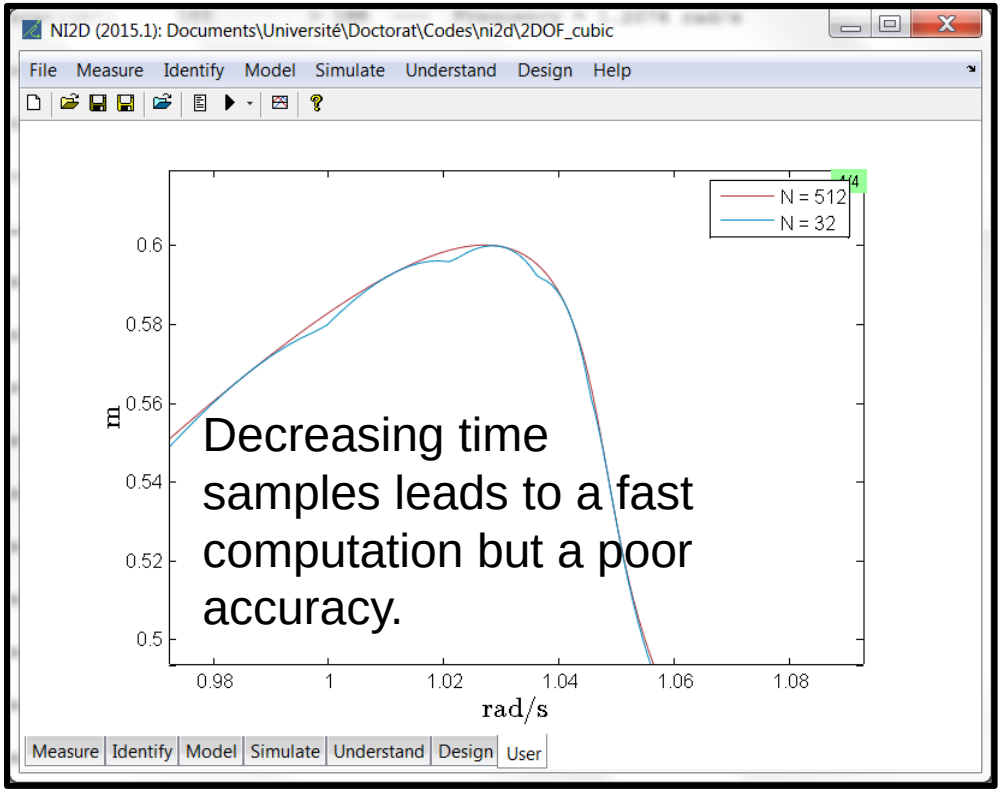
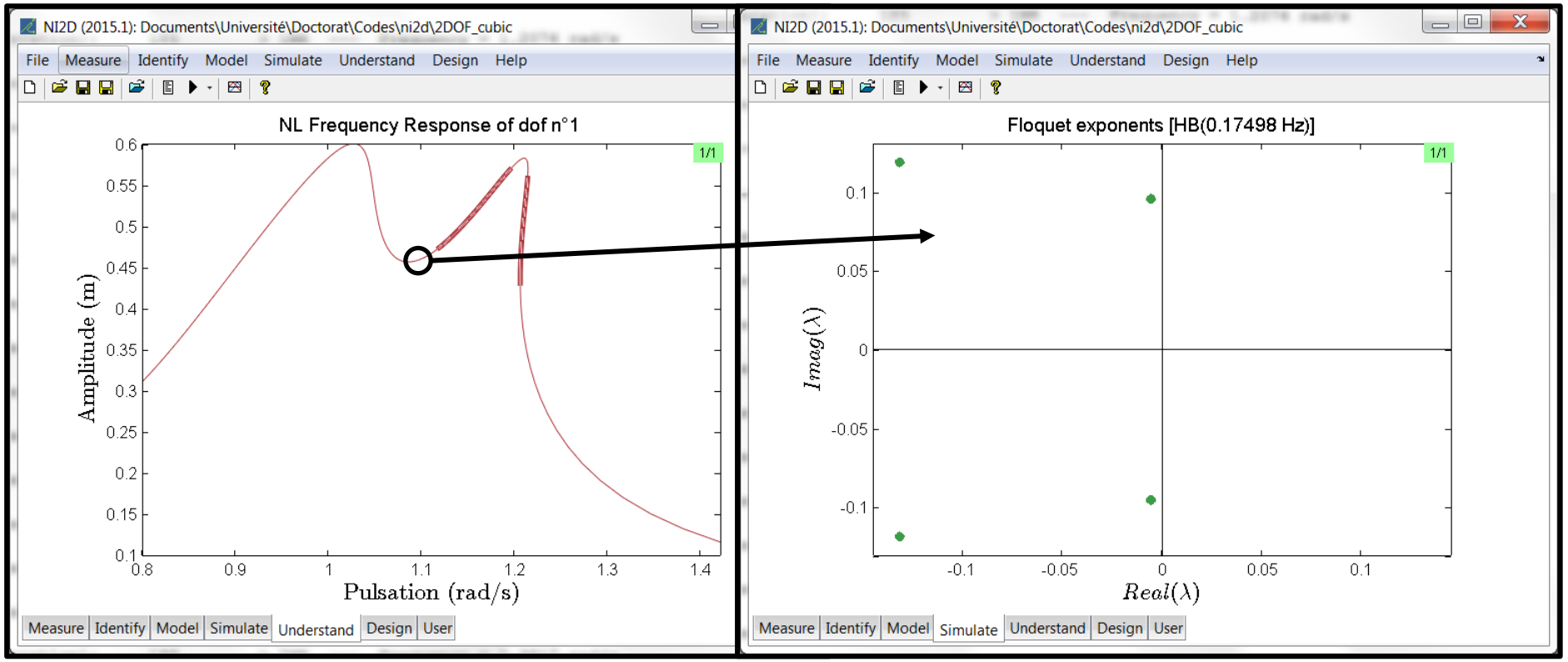


Stability Changes

- Analyze the evolution of Floquet exponents/multipliers in the vicinity of the stable/unstable transitions.



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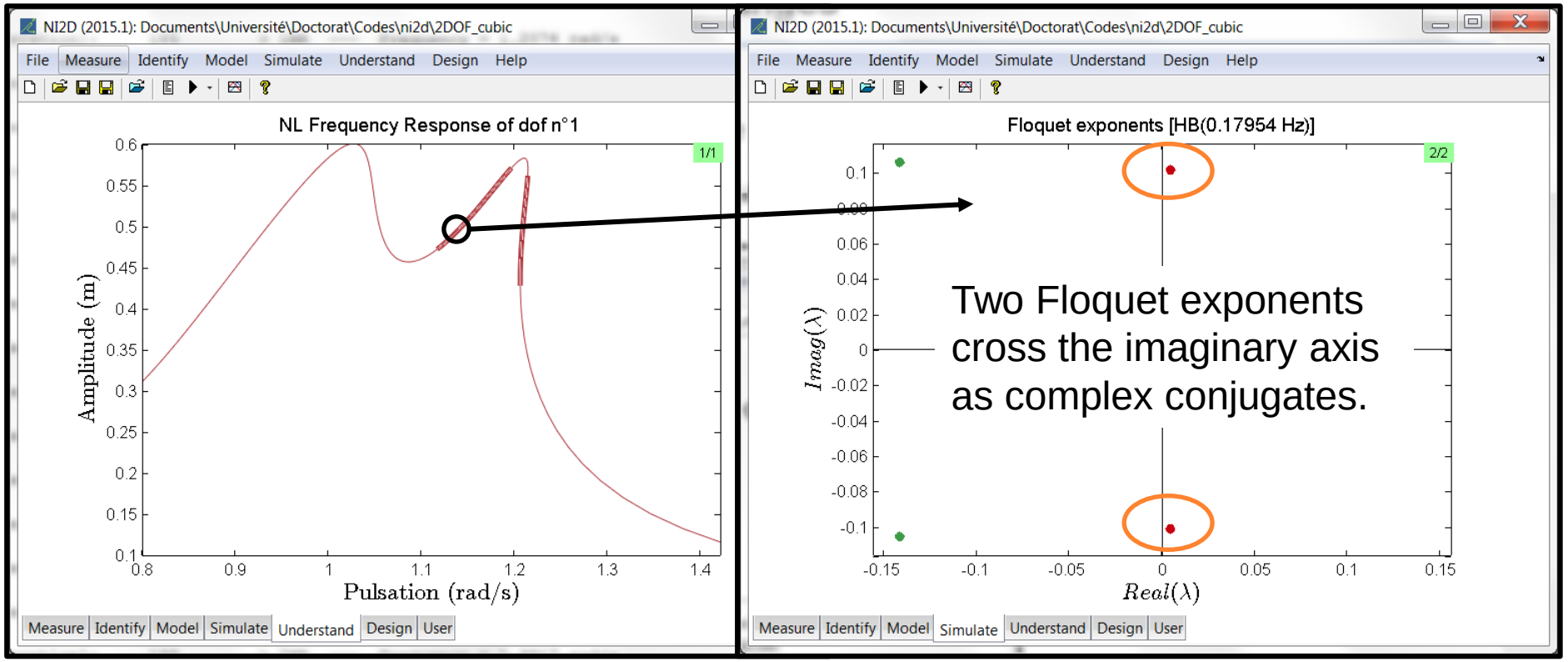

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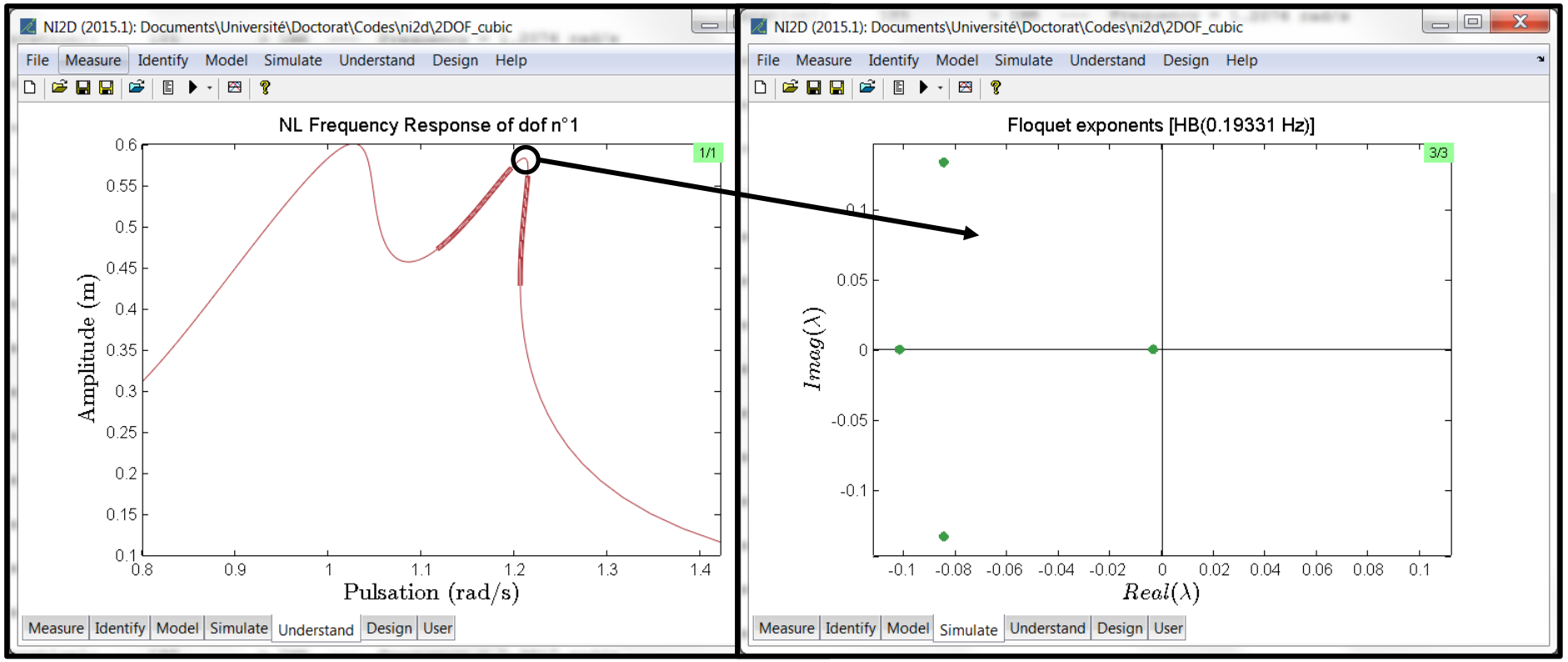

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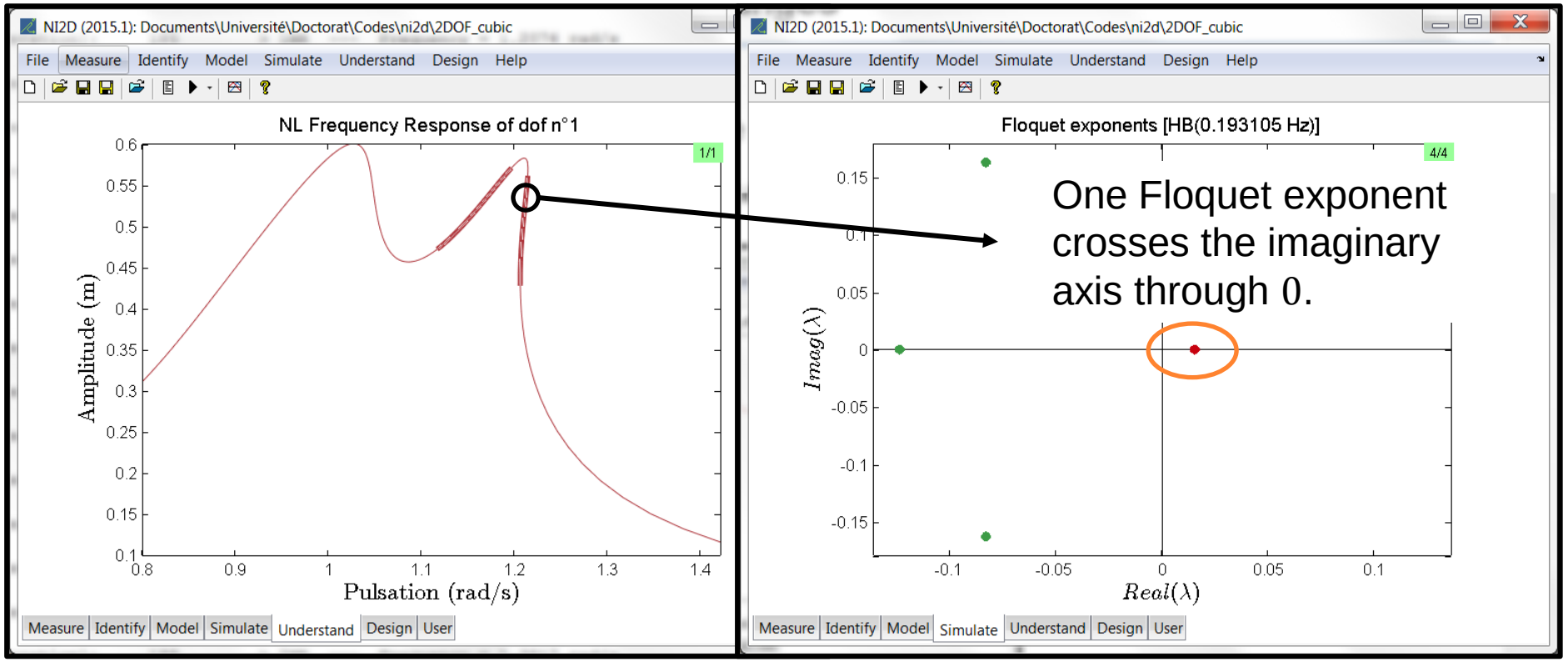
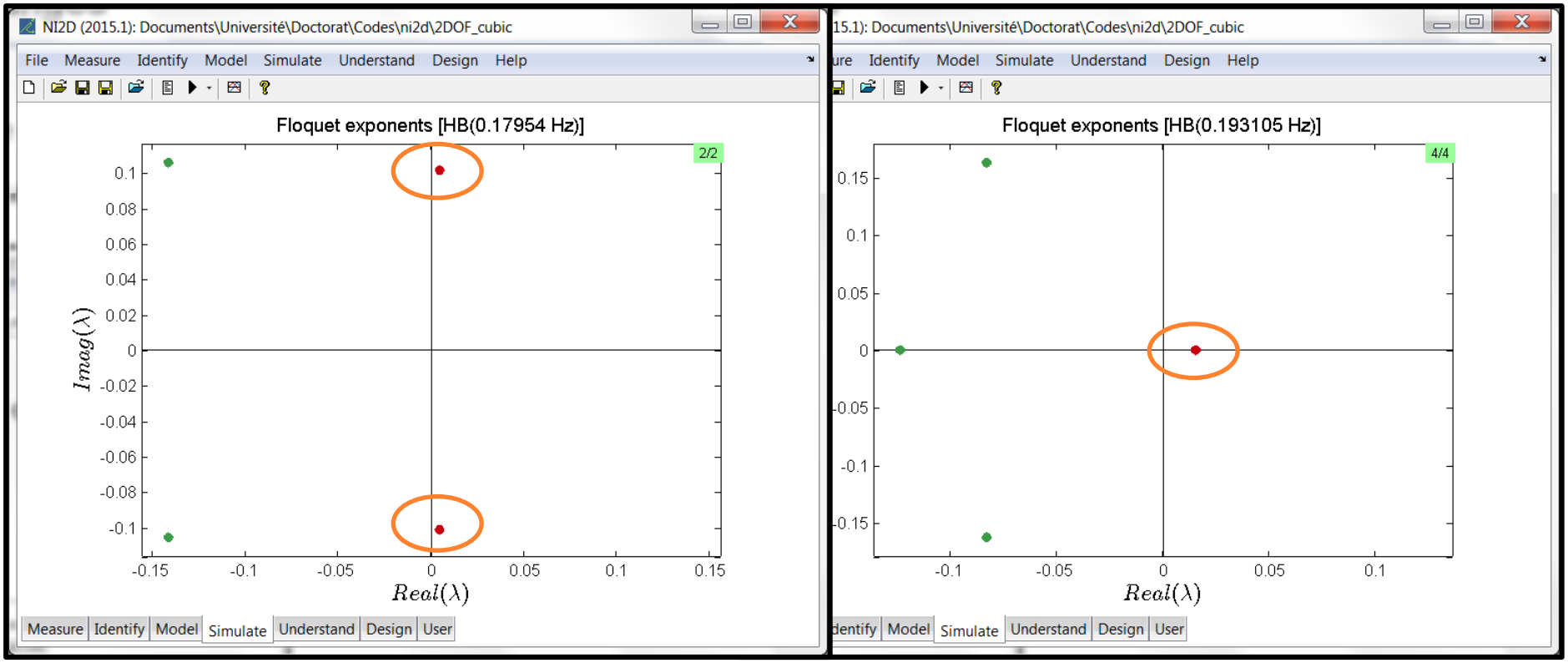


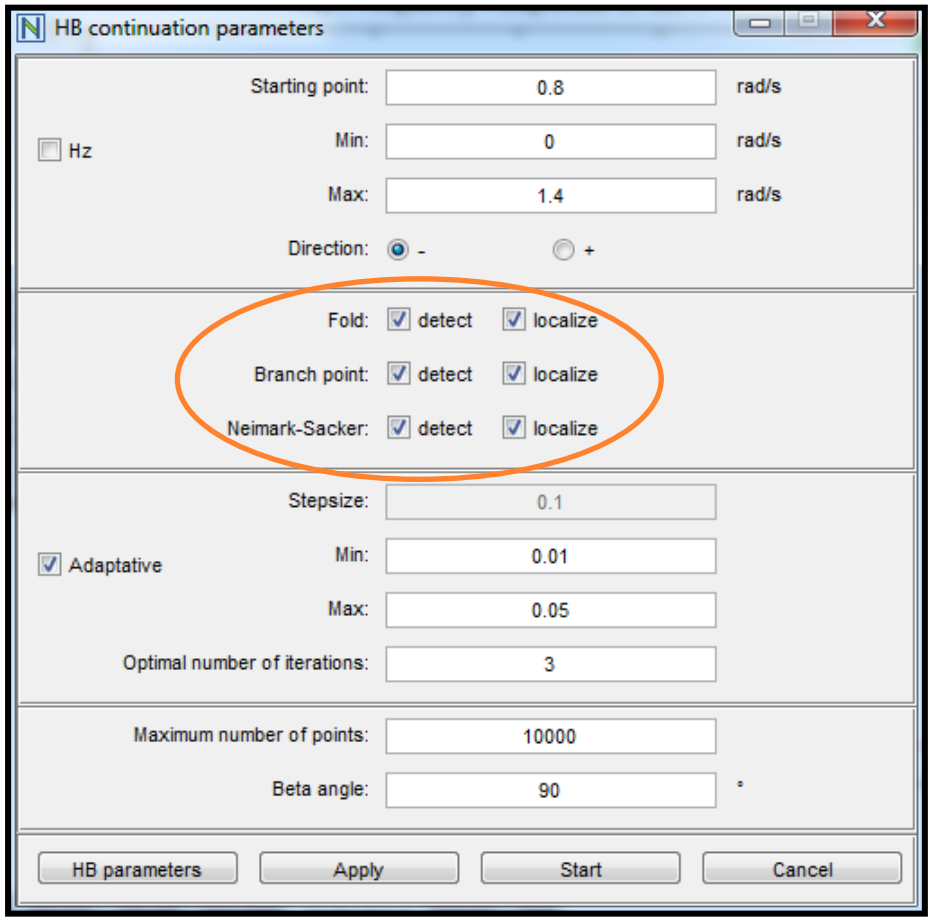
Stability Changes



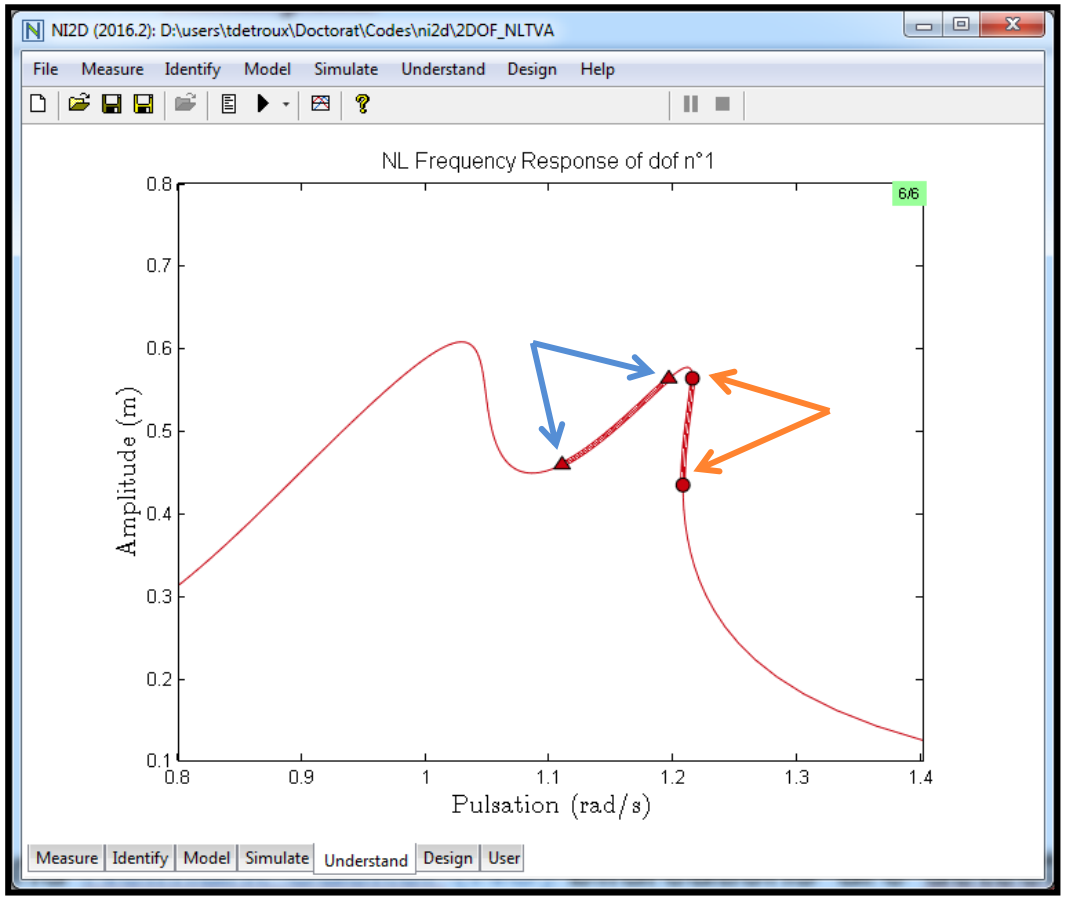
We observe different types of transition between stable/unstable regions. Are these related to bifurcations?

Bifurcation Analysis

- Select bifurcation detection and localization in the HB continuation parameters, and recalculate the NFRC.

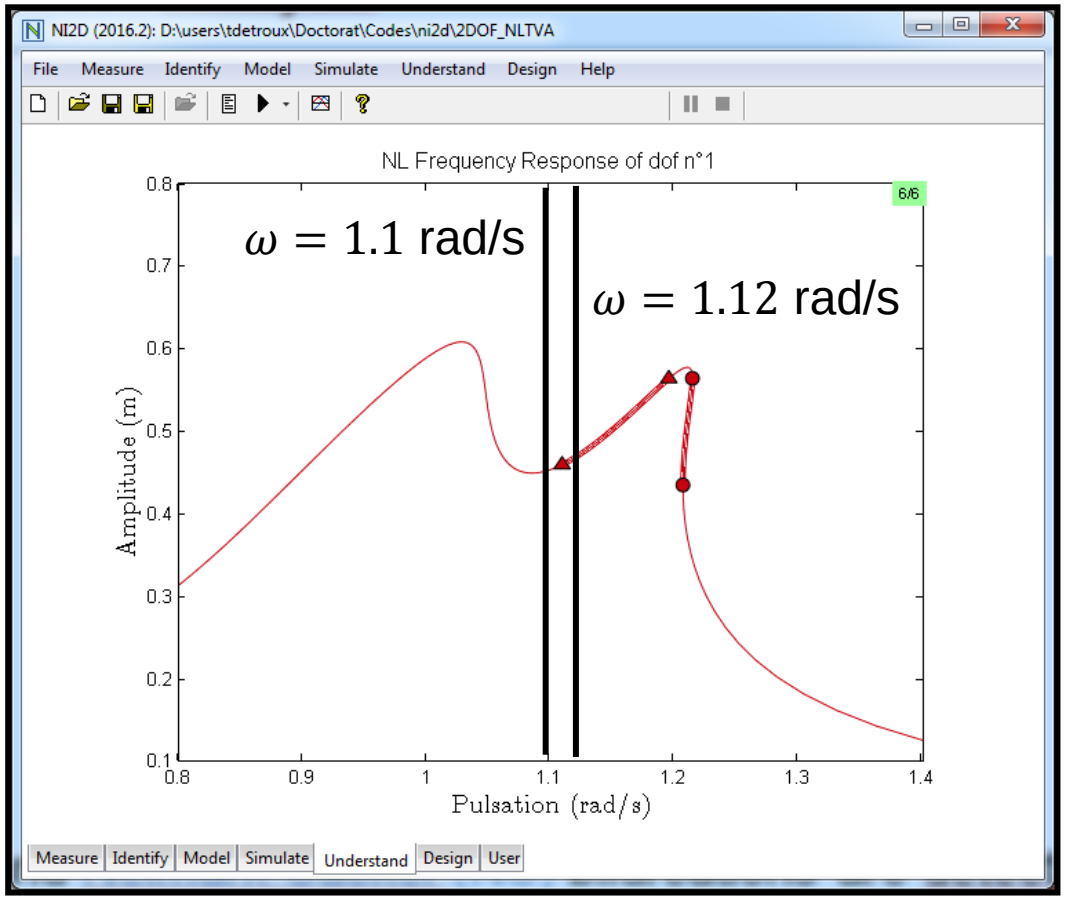


Bifurcation Analysis



Fold and Neimark-Sacker (NS) bifurcations are detected.

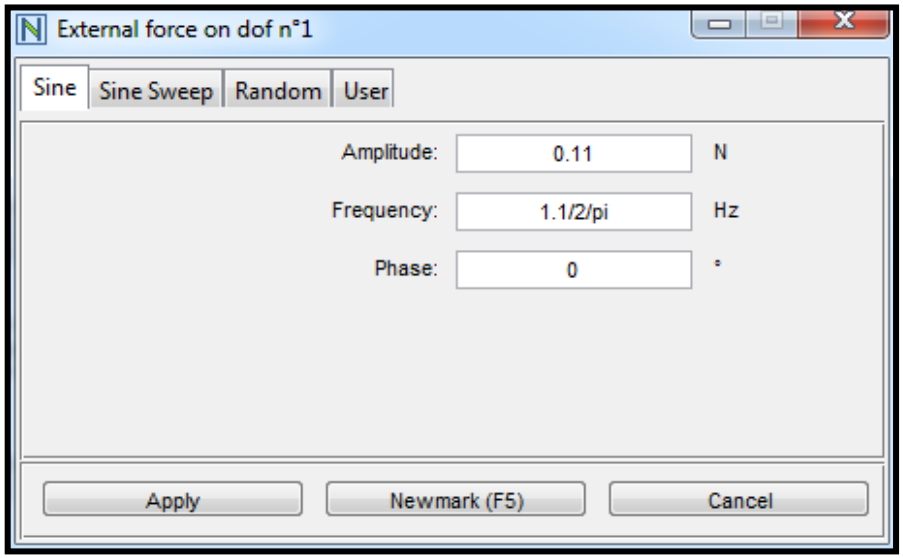
Bifurcation Analysis

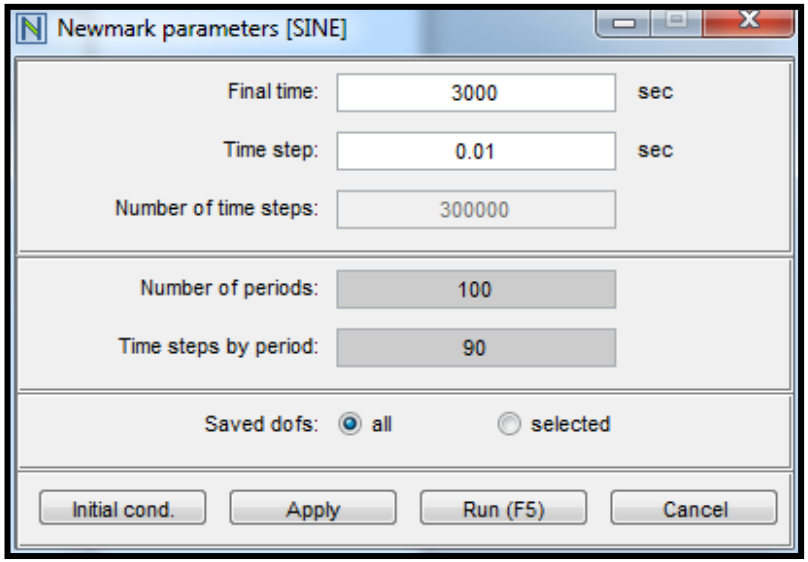


What is the influence of the first NS bifurcation on the system's response to sine excitations?

Bifurcation Analysis

- Impose sine excitations to the system with frequencies of $\omega = 1.1$ rad/s
- Use Newmark's scheme with an integration time of 3000 s.

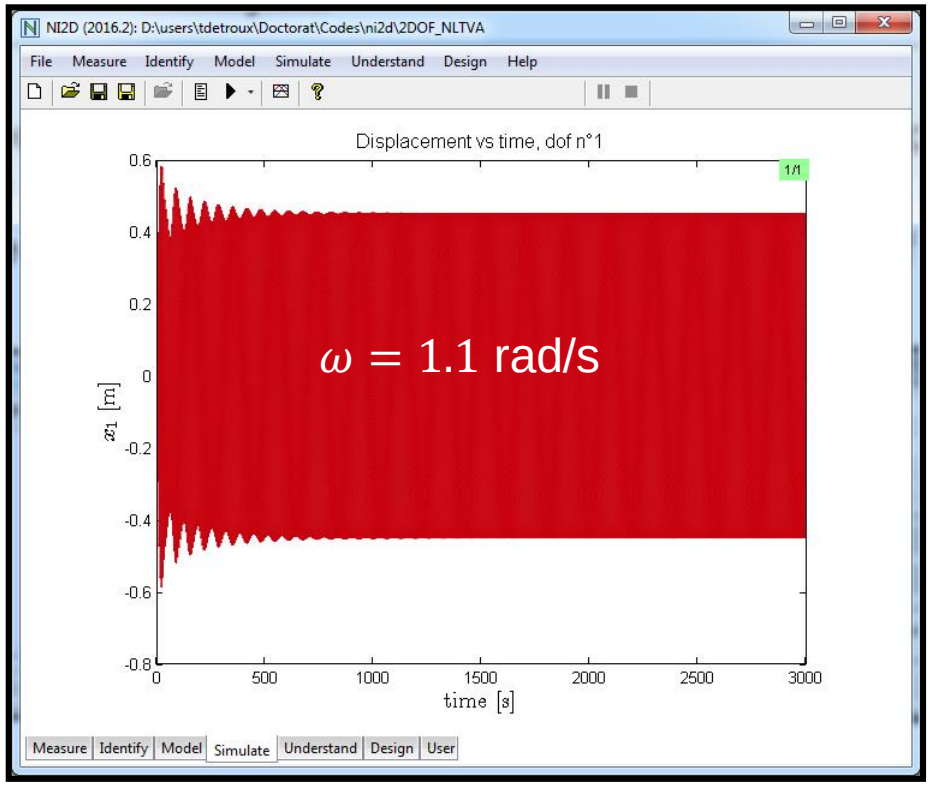


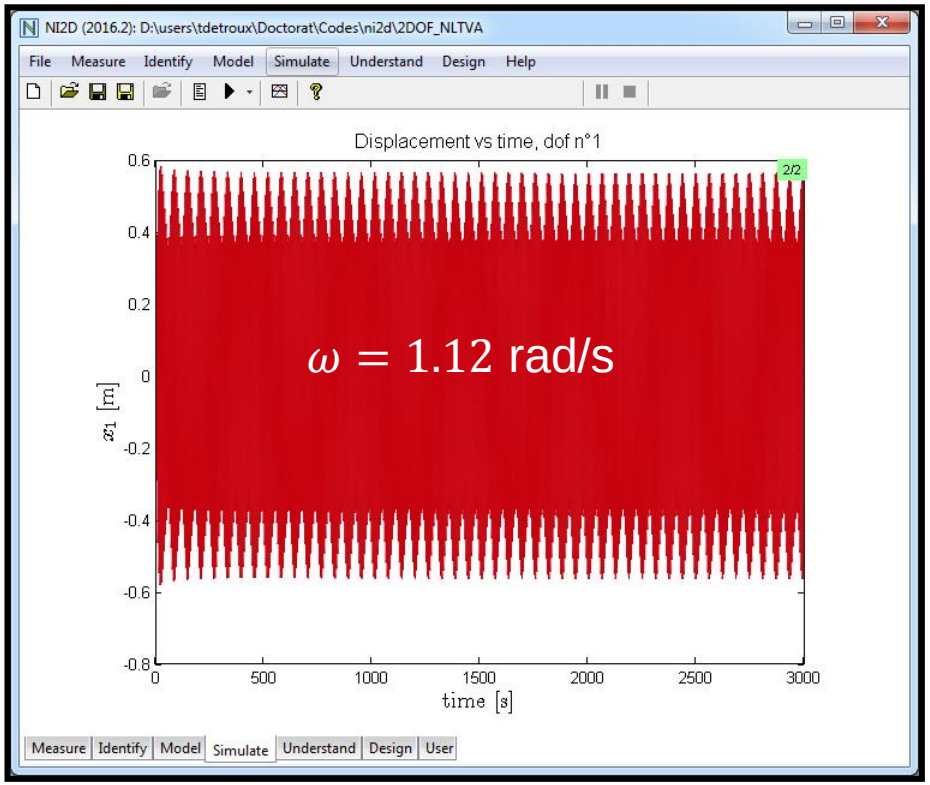


- Repeat the procedure for $\omega = 1.12$ rad/s.

Bifurcation Analysis

Before the NS bifurcation, a periodic response is stabilized.





After the NS bifurcation, a quasiperiodic response is stabilized.

Bifurcation Analysis

Because of the NS bifurcation, periodic solutions lose stability, and a branch of Neimark-Sacker oscillations emanates.