Institute of
Electrical Power Systems
Graz University of Technology

IDENTIFICATION AND VISUALIZATION OF INTER-AREA OSCILLATIONS

H. Renner

REAL SMART SECONDMENT TUGRAZ ▸ ABB-CH

INTRODUCTION

Power system electromechanical oscillation (rotor angle oscillation, small-disturbance angle stability) is an inherent property of an AC transmission system and a sub-category of the wide area of rotor angle stability. Global problems are caused by the interaction among large groups of generators and have widespread effects. They involve oscillations of a group of generators in one area against a group of generators in another area - often with a weak link - with oscillation frequencies typically ranging from 0.2 to 0.8 Hz.

PRE-PROCESSING AND FOURIER TRANSFORM

The focus was set on frequency domain analysis. Specific steps were:

- ☒ Pre-processing (unwrapping, detrending)
- ☒ Fourier transform (choice of window length and function)
- ☒ Visualization in frequency domain (carpet plots)
- ☒ Automatic mode detection (frequency/damping estimation)
- ☒ Visualization of oscillation modes (dominant oscillation paths

Besides the voltage angle deviations caused by frequency deviations, changes in load, generation redispatch and switching operations result in individual ramps or steps in each PMU voltage angle signals. Thus, a baseline removal method was applied by subtracting the fitted function s(t) from the original data.

$$s = \frac{a}{1+e^{b(t-c)}}$$

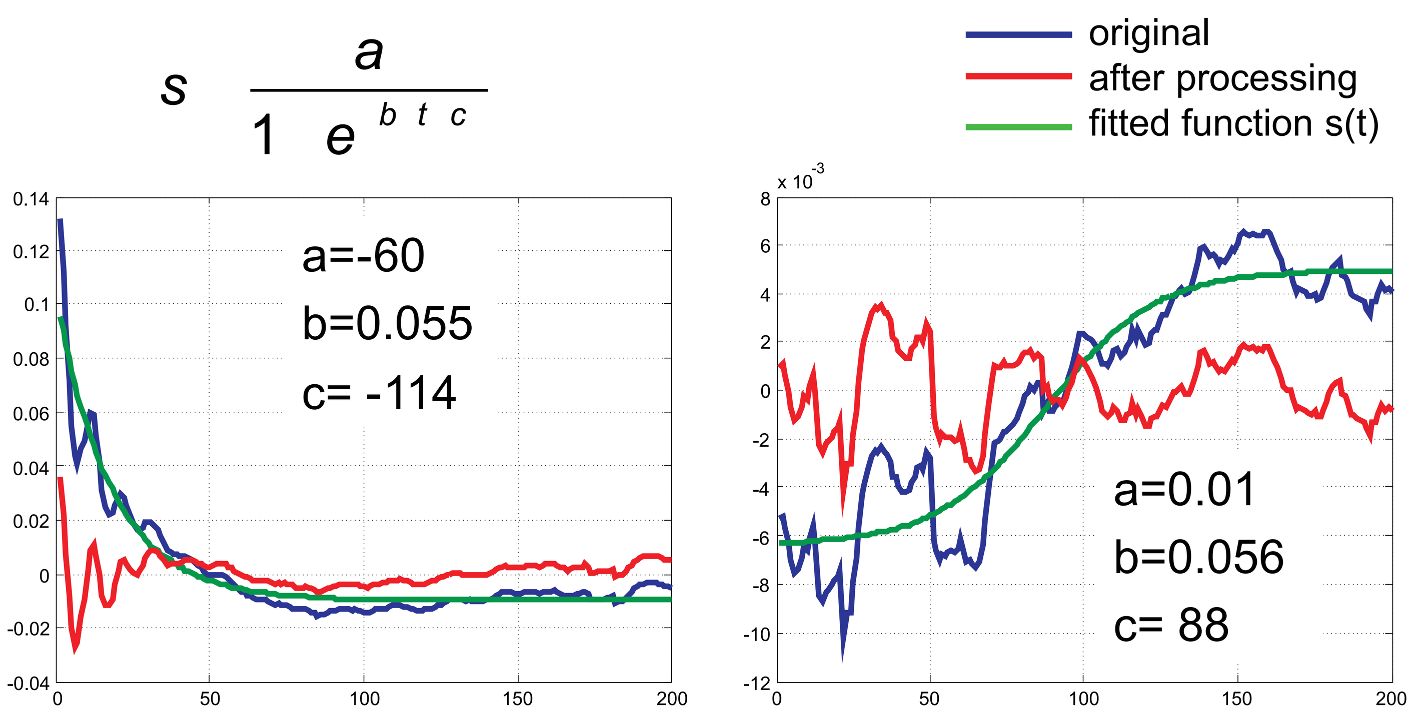

Figure 1 Two examples to demonstrate baseline removal

For the analysis of events and transients linked thereto a window length T_w of 20 s turned out to be suitable. For long term analysis of continuous operation a window length T_w of 200 s was successfully used. During the consecutive processing the DFT window was shifted by a specified time span t_w (sliding window technique). A Hamming-window was applied to avoid spectral leakage effects.

MODE IDENTIFICATION TECHNIQUE

One can assume that existing modes will be visible in consecutive windows, although amplitude might change as well as phase angles, which depend on relative position of time window. The so called modal assurance criterion (MAC) will be used to identify those modes[1]. The function of the MAC is to provide a measure of consistency (degree of linearity) between estimates of a modal vector originating from different (consecutive) time windows. Application of MAC gives a number between 0 and 1 describing the "similarity" between two modal vectors (modeshapes) Ψx and Ψy.

$$MAC_{xy} = \frac{\left|\Psi_x^T \Psi_y\right|^2}{\left(\Psi_x^T \Psi_x\right)\left(\Psi_y^T \Psi_y\right)}$$

Assuming white noise or at least noise being almost constant within a limited frequency range as excitation, the shape of the power spectrum close to the detected oscillation frequencies is used to derive the damping coefficient.

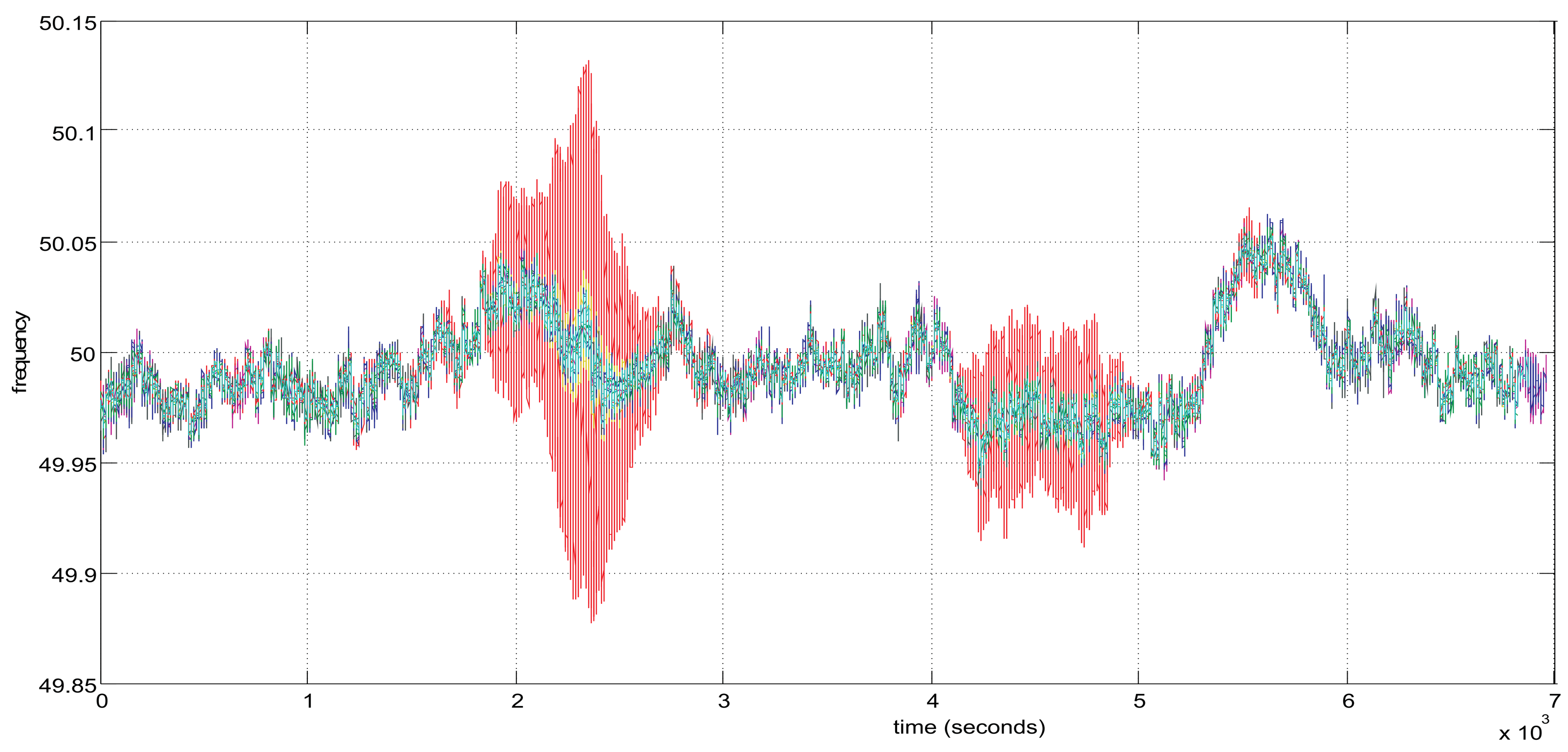

Figure 2 WAMS measurement (frequency) in Central Europe, Febr. 2011

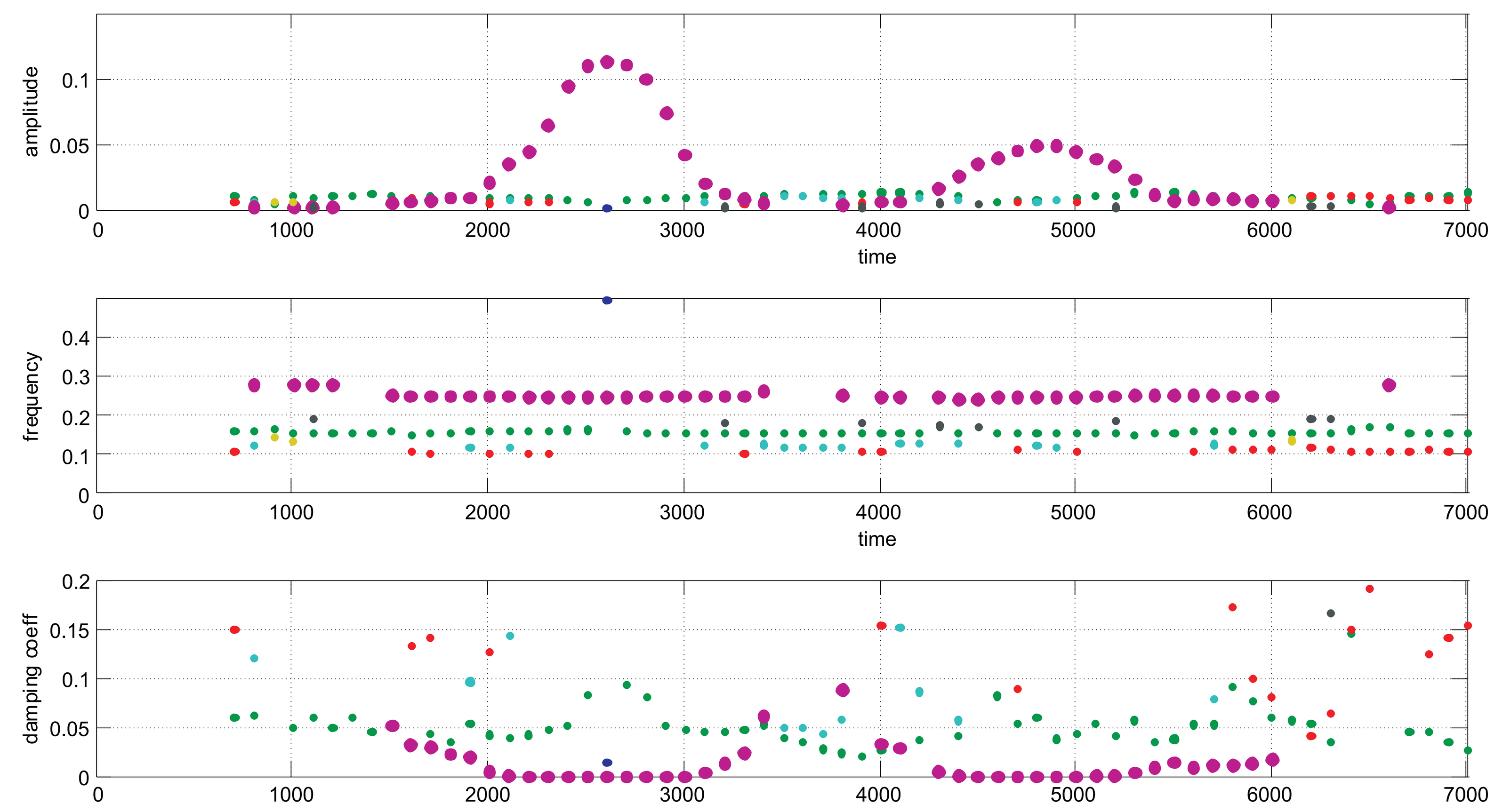

Figure 3 Mode identification (amplitude, frequency, damping), Continental Europe, Febr. 2011
0.25 Hz mode highlighted in magenta

VISUALIZATION OF DOMINANT OSCILLATION PATHS

Using simplifications as agreed for DC load flow analysis, one can calculate the unknown bus voltage phasors out of the phasors provided by analysis of the PMU measurements for each oscillation mode. Having PMUs distributed over the whole system, the calculated „oscillating power flow" gives a good picture of the oscillation mode.

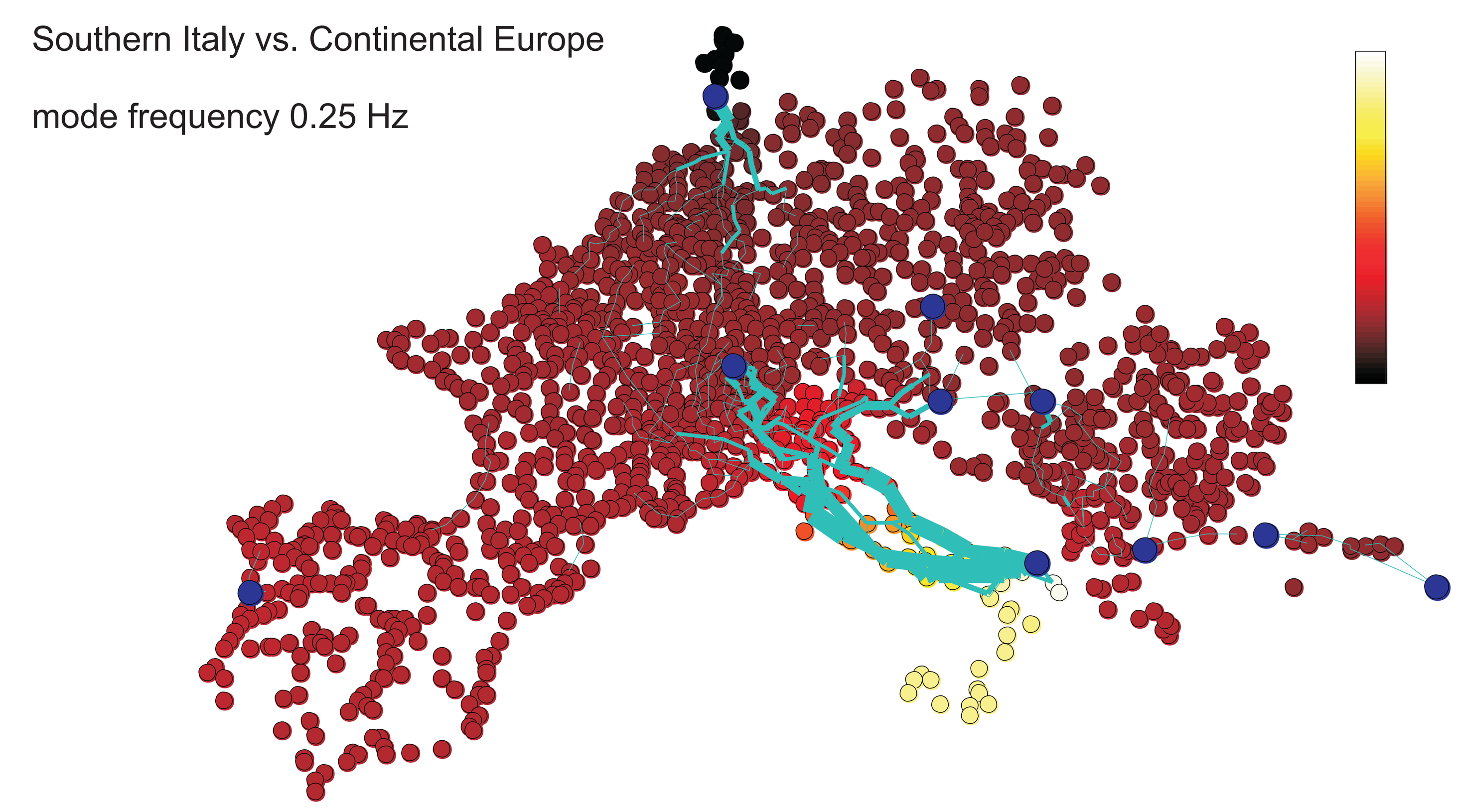

Figure 4 Geographical visualization of 0.25 Hz mode

[1] R.J.Allemang: The Modal Assurance Criterion (MAC) –Twenty Years of Use and Abuse, IMAC-XX: Conference & Exposition on Structural Dynamics, 2002

The research leading to these results has received funding from the EU FP7 program under grant agreement n° PIAP-GA-2009-251304-REAL-SMART)

Inffeldgasse 18 / I, 8010 Graz, Univ.-Prof. Dipl.-Ing. Dr.techn. Lothar Fickert, Tel. +43 316 873 7551, Fax: 7553, e-Mail: lothar.fickert@tugraz.at, www.ifea.tugraz.at