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Oscillation behaviour of the enlarged European power system under deregulated energy market conditions

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Abstract

Aimed power system simulations are carried out to analyse the bad damping behaviour of slow inter-area oscillations sporadically occurring within the European power system. To obtain application-oriented results, the simulations are carried out by a detailed power system dynamic model and compared with corresponding oscillation measurements. Using analysis methods in the time and state space, it is shown that the damping behaviour can be improved by easily applicable countermeasures.

Based on this, the foreseen enlargement of the European power system is investigated, when coupling both system ends step by step around the Mediterranean Sea to the so-called Mediterranean Ring. Also these predictive considerations lead to very interesting oscillation and damping results.

Keywords: Inter-area oscillations; Damping; Power flow; Power plants; Voltage control; Speed control

1. Introduction

Since the early stages of coupling of national grids to the interconnected European Power system, inter-area oscillations occur sporadically. Thus, after connecting the Yugoslavian and Greek (Arcidiacono, Ferrari, Marconato, & Saccomano, 1976; Weber & Welfonder, 1988) as well as the East German and Centrel (Spanner, Welfonder, Tillmann, & Zerênyi, 1998) to the West European power system (Spanner & Welfonder, 1998). With the deregulation of the electric energy market and therewith an operation under competitive market conditions (Welfonder, 2002) as well as with the enlargement of the power system toward eastern Europe system (Dudzik, Grebe, Houry, Rodriguez, & Zerenyi, 1998) and the planned closure of the so-called Mediterranean Ring (Abougarad et al., 2004) the oscillation behaviour gains accretive importance. Apart from the comparison of measurements and corresponding simulations results, this paper deals with the different possibilities of analysing the oscillation behaviour in the time and frequency domain to improve the oscillation damping within the actual and future enlarged European power system.

2. Actual behaviour of the European power system

The inter-area oscillation shown in Fig. 1 occurred on 04.04.2001 at 16:01 h during a power exchange over the eastern French border from about $P_E^{(F)} = 6.5$ GW and an Italian power import from $P_E^{(I)} = -4.5$ GW. The oscillation was triggered by a 1400-MW-outage of Block 2 Civeaux in France. This inter-area-oscillation was measured with a data logging system of the University of Stuttgart which is installed in a sub-station of the EnBW[1] close to the French/German border and with

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[1]Energie Baden-Württemberg, System Operator in the South-West of Germany.

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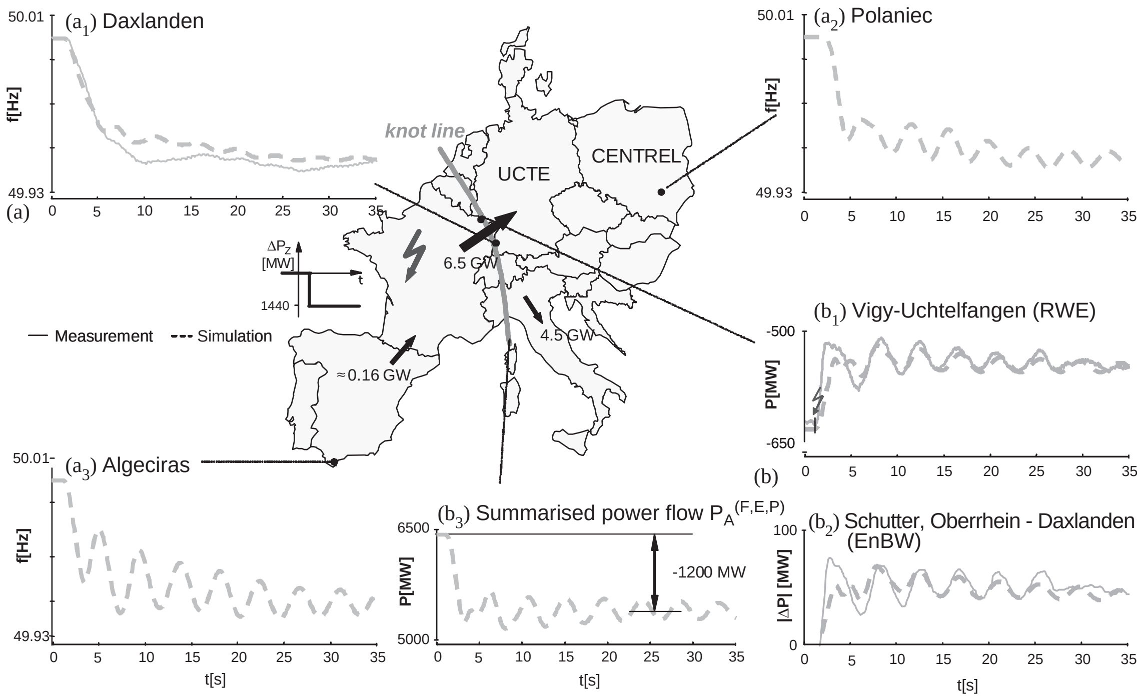

Fig. 1. Comparison of measured and simulated oscillation curves.

the powerlog-system of RWE[2]-Net in Vigy (F) and Uchtelfangen (D).

In addition, the power system behaviour during the 1400-MW-outage has been simulated by means of a detailed nonlinear power system dynamic model of the University of Stuttgart (Welfonder, Schäfer, & Asal, 1987; Kurth & Welfonder, 2001) considering the European power system with more about 620 power plant units, nearly 1200 dynamic consumer centres and more than 3000 transmission lines and transformers. The model of the European power system used for the following simulations covers the UCTE/Centrel network, is already weakly coupled by a 36 km long 380-kV-cable from Gibraltar (E) to North Africa (Morocco, Algeria and Tunisia), compare Fig. 2.

The good agreement of measurements and simulation results is shown in Fig. 1 by the comparison of lined and dashed curves. As seen in the figure, the rotating masses of the western and eastern part of the European power system are swinging against each other. This is shown by the frequencies in Algeciras (E) and Polaniec (PL) oscillating with opposite phase, see Fig. 1a_2+a_3, whereas along the oscillation knot-line in the centre of the European power system, i.e. in Daxlanden the—frequencies are not overlaid by oscillations, see Fig. 1a_1. In contrast to the frequencies, the power flows across the considered knot-line embody the strongest amplitude oscillation, see Fig. 1b_1+b_2.

[2]Rheinisch-Westfälische Elektrizitätswerke, System Operator in the West of Germany.

3. Analysis methods

For quantitative investigations of the oscillation behaviour, the following methods are applied.

3.1. Determination of the damping in the time domain

A fast way to determine the damping parameters is to estimate them directly out of the measured signals, where the natural damping is clearly defined by:

$$D_t = \frac{1}{2\cdot\pi\cdot n}\ln\frac{x_i}{x_{i+n}} \tag{1}$$

with x_i as the ith and x_{i+n} as the $(i+n)$th oscillation amplitude.

In practice, however, the determination of the damping value is combined with difficulties. This is based on the fact that the signals occurring after disturbances consist not only of the essential oscillation but usually also of overlaid ones, mostly being quite better damped. Therefore, the determination of the damping out of the measured signals will be combined with faults during the first time periods of the essential oscillation.

Under consideration of the detail analysis is the signal according to Appendix A1. This fact is shown in Fig. 3.

For the case under examination, the calculation of the damping between the 17th and 25th period leads to to $D_t = 1.25\% < D_{min} = 3\%$ (CIGRE, 1996), i.e. the oscillation is not sufficiently damped (see Fig. 4).