Calculation of electromechanical eigenvalues based on measured instantaneous power waveforms

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Abstract **The paper presents the results of calculations of the eigenvalues (associated with electromechanical phenomena) of the state matrix of the Polish National Power System model on the basis of analysis of the measured instantaneous power disturbance waveforms of generating units in Łaziska Power Plant. The method for calculations of electromechanical eigenvalues used in investigations consists in approximation of instantaneous power disturbance waveforms in particular generating units with use of the waveforms being a superposition of the modal components associated with the searched eigenvalues and their participation factors.**

Keywords **power system, electromechanical eigenvalues, transient states, waveform recovery.**

I. Introduction

Maintaining the angular stability of a power system (PS) is one of the most important aspects of the system operation. The PS angular stability can be assessed with use of stability factors calculated on a basis of the PS state matrix eigenvalues [1], [2]. The eigenvalues can be calculated with good accuracy from analysis of the actual disturbance waveforms occurring in the PS after various disturbances [1]. The aim of this paper is to calculate eigenvalues (associated with electromechanical phenomena) of the state matrix of the Polish Power System (PPS) model interfering in the instantaneous power waveforms of the generating units working in Łaziska Power Plant.

The power system model linearized around the working point is described by the state and output equations [1]. For a disturbance being a step change in the j-th input quantity $\Delta \boldsymbol{U}_j(t) = \Delta U \mathbf{1}(t)$, the waveform of the i-th output quantity (for $\boldsymbol{D} = \mathbf{0}$ [1]) is given by:

$$\Delta Y_i(t) = \sum_{h=1}^{n} F_{ih} \lambda_h^{-1} \left(e^{\lambda_h t} - 1 \right) \Delta U, \qquad (1)$$

where: λ_h – h-th state matrix eigenvalue, F_{ih} – participation factor of the h-th eigenvalue in the i-th output quantity waveform [1]. The eigenvalues associated with motion of generating unit rotors (electromechanical eigenvalues) are of decisive significance.

II. Exemplary calculations

The method for calculating electromechanical eigenvalues used in investigations consists in approximation of instantaneous power waveforms in particular generating units by means of expression (1). The eigenvalues and their participation factors are selected iteratively so as to minimise the objective function value [1]:

$$\varepsilon_{\mathrm{w}}(\boldsymbol{\lambda}, \boldsymbol{F}) = \sum_{i=1}^{N} \left(\Delta P_{i(\mathrm{m})} - \Delta P_{i(\mathrm{a})}(\boldsymbol{\lambda}, \boldsymbol{F}) \right)^2, \qquad (2)$$

where: $\boldsymbol{\lambda}$ – vector of eigenvalues, $\boldsymbol{F}$ – participation factor vector, index m denotes the approximated waveform and index a – the approximating waveform. A hybrid algorithm consisting of genetic and gradient algorithms was used for minimisation of the objective function (2) [1].

There were analysed the instantaneous power waveforms occurring after introducing the disturbance in the form of a step change of the voltage regulator reference voltage of different height in unit KOP113 and unit KOP213 in Łaziska Power Plant. These waveforms contain only one, significant modal component associated with the electromechanical eigenvalues: λ_{L1} in the waveform of unit KOP113 and λ_{L2} in the waveform of unit KOP213. In Table 1 there are listed the results of calculations of the eigenvalues based on the measured instantaneous power waveforms. For instance, Fig. 1 shows the instantaneous power waveforms in unit KOP213 in case of the step disturbance of the height ΔV_{ref} equal to –3% of the steady value V_{ref0} of the voltage regulator reference voltage.

TABLE I
CALCULATION RESULTS OF EIGENVALUES

Unit		for $\Delta V_{\mathrm{ref}} = -3\%\ \Delta V_{\mathrm{ref0}}$	for $\Delta V_{\mathrm{ref}} = 3\%\ \Delta V_{\mathrm{ref0}}$
KOP113	λ_{L1}, 1/s	0,8823±j7,7264	–1,0176±j8,0020
KOP213	λ_{L2}, 1/s	–0,8603±j8,2592	–1,0140±j8,5071

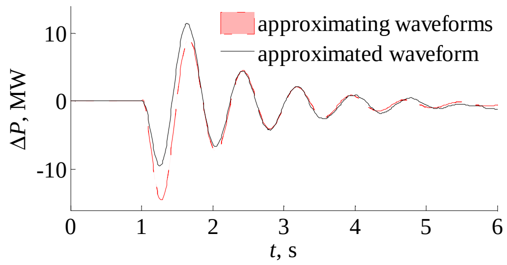

Fig. 1. Exemplary waveform of the instantaneous power deviation

III. Conclusion

The calculation results of electromechanical eigenvalues based on the measured instantaneous power waveforms recorded in Łaziska Power Plant are different depending on the sign of the introduced step disturbance amplitude. On the basis of the simulation calculations carried out, one can conclude that the result obtained in the case of the disturbance of a negative amplitude is more accurate, since in that case the effect of nonlinearities and limits on the instantaneous power waveforms is smaller.

IV. References

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