UDC 621.313.322-81

S. M. Baliuta, Doctor of Technical Sciences, Professor
National University of Food Technologies (UKRAINE)
Iu. V. Kuievda,
National University of Food Technologies (UKRAINE)

SYNTHESIS OF ROBUST INTERCONNECTED SYSTEM STABILIZERS FOR TURBINE GENERATOR UNITS UNDER UNCERTAINTY

Annotation. The system of interconnected turbine generator unit control (SIC) is proposed. The method of active identification of the continuous matrix transfer function of the turbine generator unit operating in parallel with the electric system is given. The identification is carried out with the aim of further synthesizing the H∞-robust controller under uncertainty at different operating points of the turbine generator unit, for this purpose, in the identification process, the boundaries of the uncertainty of the transfer function are determined.

Key words: turbine generator unit, uncertainty, robustness, system stabilizer, identification.

During operation of the turbine generator unit (TGU), in emergency and regular operating modes in parallel with the electric power system (ES) there is a problem of the stability of its operation and effective dumping of electromechanical oscillations of the TGU shaft. Currently this problem is solved mainly due to the automatic excitation regulator (AER) of turbine generator (TG) [2]. The capabilities of other TGU regulators, such as for example a turbine speed governor (TSG), are used indirectly and not optimally.

The purpose of this study is to create an interconnected control system of TGU (SIC), which, using additional control channels of AER and TSG, along with equipment such as asynchronous damping device (ADD) [3], would solve the problem of operational stability and dumping of electromechanical oscillations of the TGU's shaft.

The following tasks have to be solved for the development of the SIC: the development of a SIC structure for coordinating the work of different TGU subsystems; building of TGU, ES and ADD mathematical models of different complexity for separate stages of research; identification of TGU and ES models and their limits of uncertainty; designing the ADD and defining its parameters; synthesis of robust regulators of SIC taking into account specified uncertainties; computer simulation of the synthesized regulators for different operating modes TGU and ES, including evaluation of the SIC influence on the fatigue damage of the TGU's shaft.

In more detail, we will focus on the task of identifying TGU and ES models with the boundaries of their uncertainties for the synthesis of regulators, whose main purpose is damping electro-mechanical oscillations of the TGU's rotor.

Consider the ES and TGU model, including TG, AER, turbine and TGS. In this model, we fix two inputs of the u_{AER}, u_{TGS} – stabilizing control channels of AER and TGS, and one output y_{dw} – rotational frequency of the TGU's rotor. The continuous matrix transfer function G of such a model can be represented as follows

$$G(s) = \begin{pmatrix} G11(s) & G12(s) \end{pmatrix}, \quad Gij(s) = \left(\sum_{k=0}^{m} bij_k s^k \right)^{-1} \sum_{k=0}^{n} aij_k s^k \ . \tag{1}$$

The task is to identify the function G in the form (1) and the limits of its uncertainty by the set of discrete measurements of input and output signals. We restrict ourselves to one source of uncertainty – the TGU's operating point.

We fix one "basic" function G and denote it G_{base}. Then a set of functions under uncertainty can be represented as a so-called additive model

$$G = G_{base} + \Delta W \ , \tag{2}$$

where $\Delta = \begin{pmatrix} \Delta 11 & \Delta 12 \end{pmatrix}$, $\|\Delta\|_\infty < 1$ is the normalized uncertainty, $\|g\|_\infty$ – the norm in the space of all stable regular fractional-rational functions, and W is the weighting function, which usually also belongs RH_∞. Then the problem can be reformulated as the finding of transfer functions G_{base} in the form (1) and W.

Let's first consider the G_{base} identification task. Assume that G_{base} is matched to the nominal TGU operating mode, which corresponds to the nominal value of the active power P_{nom} and the reactive power

Q_{nom} according to the nominal power factor value $\cos\varphi_{nom}$. We select the active method of identification by generating data sets for each channel "u_{AER} - y_{dw}" and "u_{TGS} - y_{dw}" from individual experiments. As inputs, we select two types of signals to compare the quality of the identification of the function G for each one: "white noise" and a linearly modulated signal, also called "chirp"-signal. We perform identification according to the time discrete series, using one of the "direct" methods – the prediction error minimization method (PEM) [1]. As a result, we have the value of the G_{base} coefficients as in (1).

To determine the weighting function W, we identify several G_{Pi} functions at different operating points that correspond to the power values (P_1, Q_1), (P_2, Q_2) … (P_k, Q_k) within the limits defined by the TA operating conditions. We construct the frequency response differences of the basic and identified functions $G11_{Pi} - G11_{base}$, $G12_{Pi} - G12_{base}$, and determine the maximum magnitudes of these two families, as the upper enveloping curves. Using these curves we restore the minimum-phase transfer functions $w11$ and $w12$, by which we construct the matrix weighting function $W = \begin{pmatrix} w11 & 0 \\ 0 & w12 \end{pmatrix}$.

Within the study, input-data sets in the form of "white noise" and "chirp"-signals and output data were generated, using which, respectively, transfer functions G_{wn} and G_{ch} were identified as an additive uncertainty models (2). A comparison of the identified G_{wn} and G_{ch} functions with G_{teor} was also performed, where G_{teor} was obtained from the theoretical TGU and ES model by linearizing and decreasing its order by the Schur's method [2]. The comparison was carried out in the frequency range and it was showed the coincidence of the frequency response of all functions with sufficient accuracy in the midrange region, as well as the fact that G_{ch} gives a better approximation than G_{wn}.

As a solution to one of the stages of the creation of a SIC, the method of active identification of a linear continuous mathematical model of TGU in the form of a matrix transfer function and the determination of the boundaries of its uncertainty when changing the TGU operating points are given. This function is used later for the synthesis of the H_∞-robust system stabilizer, which damps the electromechanical oscillations of the turbine generator rotor. As a result of numerical experiments, the function G in the form of an additive model (2) was identified, its proximity in the limited frequency range to the theoretical TGU transfer function was established.

References

1. Garnier H., Mensler M., Richard A. Continuous-time model identification from sampled data: Implementation issues and performance evaluation. International Journal of Control. 2003. Vol. 76. Issue 13. P. 1337–1357.
2. Pal B., Chaudhuri B. Robust Control in Power Systems. NY. Springer Science+Business Media, Inc. 2005. 206 p.
3. Baluta, S. An asynchronous damping device for decreasing shaft swings of powerful turbogenerators. The 8th Central European Congress on Food: book of abs. 2016. P. 42.