Measurement parameter estimation of the model of a synchronous generator working in thermal electric power plant

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Abstract **The paper presents parameter estimation of the model of a turbogenerator of rated power P_N=50 MW working in a thermal electric power plant. The disturbance waveforms measured at a step change of the reference voltage of the generator voltage regulator – for generator parameters in *d* axis as well as at active and passive load rejection for generator parameters in *q* axis were the basis for estimation. The problem of measuring the generator power angle as well as processing and filtrating the measurement signals is discussed.**

Keywords **Synchronous generator, recording of transient waveforms, GENROU model, parameter estimation, load rejection.**

I. Introduction

Large and medium synchronous machines are the basic source of electrical energy in a power system (PS). The accuracy of simulation calculations concerning different PS normal and emergency states depends on the system mathematical models assumed, in particular the synchronous generator models and their parameters.

The paper presents investigation results of Skoda 6H6372/2 turbogenerator of rated power P_N=50 MW working in Thermal Electric Power Plant Halemba. Parameter estimation of the GENROU model was performed on the basis of measurements of the no-load characteristic and transient waveforms caused by introducing disturbances of the generator steady state operation.

II. Measurement investigations of the turbogenerator

Investigations of the turbogenerator were carried out under steady and transient state conditions. The generator no-load characteristic was determined in the steady state. In transient states there were recorded waveforms of electrical and mechanical quantities for two kinds of disturbances:

- step change of the voltage regulator reference voltage of the generator at no-load,
- active and passive generator load rejection (P_0= 5 MW, Q_0= 3.5 Mvar) obtained by opening the generator main switch.

In the generator transient states there were recorded the armature voltages and currents, the exciting current and the field voltage and the shaft position determined on the basis of a signal from the encoder fixed to the generator shaft. A KARED disturbance recorder of type RZ1 whose sampling frequency equaled 32 kHz was used for recording the dynamic waveforms.

III. Measurement signal processing

Based on the waveforms of the armature phase voltages and currents, there were determined their axial components in *d* and *q* axis with use of Park transformation [4] according to the relationship:

$$W_{d,q} = \boldsymbol{C}\big(\vartheta(t)\big)\cdot W_{A,B,C}\,, \tag{1}$$

where *W* is the voltage or current instantaneous value. The angle $\vartheta(t)$ in the transformation matrix $\boldsymbol{C}$ determines position of axis *d* in relation to the axis of phase *A* and is equal to:

$$\vartheta(t) = \vartheta_0 + \vartheta_G(t)\,, \tag{2}$$

where ϑ_0 is the initial angle (at the time instant $t = 0$) assumed in such a way that, after transformation of phase voltages $V_{A,B,C}$, the axial voltage in axis *d* at no-load steady state should be equal to zero. The angle $\vartheta_G(t)$ equals the generator shaft position angle determined based on the encoder signal. The power angle $\delta(t)$ was determined on the basis of the axial quantities after transformation.

A series connection of the moving average algorithm and a third order Butterworth digital filter with cutoff frequency 30 Hz was used for filtration of the measurement waveforms [1]. Filtration was performed for the axial components of the armature voltages and currents, which allowed eliminating the fundamental component 50 Hz making the filtration difficult. Fig. 2 shows the generator exciting current I_{fd} waveforms before and after filtration.

The sampling frequency of the filtered waveforms was reduced from 32 kHz to 200 Hz with the interpolation method, which allowed decreasing the number of the signal samples in the objective function and shortening the computation time.

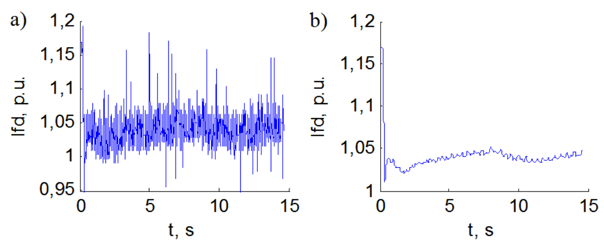


Fig. 2. Generator exciting current before (a) and after (b) filtration

The measurement waveforms were recalculated into relative units, assuming the generator system of relative units for the armature quantities and the regulator (excitation) system for the excitation quantities.

The mean value of each axial quantity waveform was calculated for the steady state, before occurrence of the disturbance. In the case of the field voltage E_{fd} and exciting current I_{fd} waveforms, there was introduced correction of the signal levels so that the field voltage under steady state conditions was equal to the exciting current in relative units.

IV. RESULTS OF GENROU MODEL PARAMETER ESTIMATION

Based on the 6H6372/2 turbogenerator measurement results, there was performed parameter estimation of the generator GENROU model [3] expressed by the standard reactances and time constants of the steady, transient and subtransient state.

Parameter estimation of the GENROU model was carried out by the program PARZW developed in Matlab/Simulink environment. Stator axial currents I_d, I_q, field voltage E_{fd}, rotor speed deviation $\Delta\omega$ and load angle δ, were assumed to be input signals, while stator axial voltages V_d, V_q and exciting current I_{fd} were assumed to be output ones (Fig. 3).

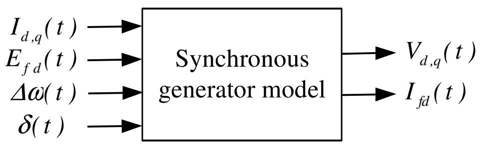


Fig. 3. Synchronous generator input and output signals

Parameter estimation was performed with the least square method minimising the deviations between the waveforms of the output quantities measured and calculated on the basis of the model considered [2]. The Newton gradient optimisation algorithm with constraints was used for minimisation of the objective function worked out [2].

Figs. 4 and 5 show the parameter estimation results of the generator GENROU model. The armature voltage waveforms measured and calculated for the derived parameter values under disturbance conditions caused by a step change of the generator voltage regulator reference voltage are compared in Fig. 4. Comparison of the exciting current waveforms under disturbance conditions caused by arbitral load rejection as well as calculated parameter values is depicted in Fig. 5.

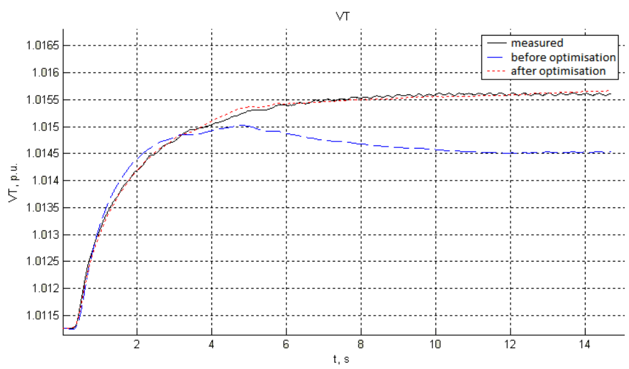
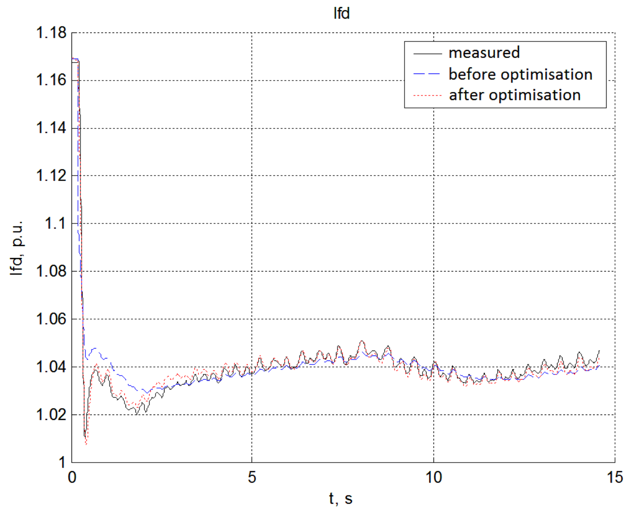


Fig. 4. Armature voltage: measured, before and after optimisation, for a step change of the voltage regulator reference voltage by +5%



Parametry modelu generatora GENROU

Nazwa:	Ra	Tpdo	Tppdo	Tpqo	Tppqo	H	D	Xd	Xq	Xpd	Xpq	Xpp	Xl	S10	S12
Wartość początkowa:	0.00183	9.5296	0.09793	1.2	0.08	3.5	0	1.7256	1.7	0.20625	0.45728	0.18611	0.13673	0.08023	0.49994
max:	0.0019	15.4	0.18	1.2	0.08	4.2	0	2.3	1.7	0.324	0.516	0.216	0.1668	0.1	0.5
min:	0.0013	3.8333	0.06	0.6583	0.0442	2.9167	0	1.4	1.3	0.15	0.3	0.12	0.1158	0.001	0.1
Optymalizuj:	☑	☑	☑	☐	☐	☐	☐	☑	☐	☑	☐	☑	☐	☑	☑
Wyniki:	0.00147	8.9405	0.10743	1.2	0.08	3.5	0	1.7511	1.7	0.20312	0.45728	0.13767	0.13673	0.08294	0.5

Fig. 5. Exciting current: measured, before and after optimisation, for arbitral load rejection as well as parametr estimation results of generator GENROU model in d and q axis

V. CONCLUSIONS

The presented method for parameter estimation of synchronous generator mathematical models uses results of measurements taken at the generator at the generator work stand. The measured waveforms of electrical and mechanical quantities are affected by noises and disturbances which should be carefully eliminated with signal processing digital methods.

As a result of investigations, there was obtained good approximation of the measured and, next, appropriately processed disturbance waveforms by the generator model expressed by its parameters. There were obtained the reliable parameters of the GENROU model of the synchronous generator working in the thermal electric power plant.

The measurement tests conducted were relatively simple and safe for the generator.

VI. ACKNOWLEDGEMENTS

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VII. REFERENCES

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