THE INFLUENCE OF EXCITATION SYSTEM`S PARAMETERS TO THE POWER SYSTEM STABILITY

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***Abstract*:** Paper deals with analysis of possible optimization of synchronous generator's excitation system. Authors examine influence of excitation system's parameters to the dynamics of transient processes in the power system. Authors investigated optimal parameters of excitation system of the Kegums hydro power plant. For optimization of parameters genetic algorithms was used.
The problem of the mutual influence of excitation systems of neighbor power plants was investigated.
Investigation of transient processes using developed model proved that optimization of excitation parameters improves efficiency of regulation of excitation system, damping of active power oscillation and in some cases can prevent out-of-step condition.

***Keywords*:** power oscillation damping, power system stabilizer, optimization of excitation parameters.

1. Introduction

The quality as well as reliability of electrical energy transmitted to consumers is one of the main parameters for successful operation of the power system. The problem of power oscillation damping in the power system is solved using power system stabilizer (PSS) as additional voltage regulation loops. A lot of work has been dedicated to this problem [1, 2, 3]. Kegums hydro power plant (HPP) is one HPP creating cascade of the three HPP at the Daugava river. Modernization of equipment in the Latvian power system takes place during the last decades. Excitation system of the Kegums HPP is an old fashioned АРВ-СД excitation system with different stabilization parameters. Few other power plants are with modernized excitation systems. Hence, parameters of excitation system of the Kegums HPP are no more optimal. Paper deals with analysis of parameters of excitation system of Kegums HPP. Optimal parameters allow to improve power oscillation damping. Possible adaptive approach for more effective oscillation damping is suggested.

2. Description of Kegums HPP and excitation system

The construction of Kegums HPP was finished in 1979. Since that time three generators of 64 MW capacities are in service. Generator voltage is 13.8 kV. Excitation system is АРВ-СДП1 type developed in the former USSR [4].
Transfer function of excitation system:

$$U_{reg}(p) = \left(\Delta U(p)\left(K_U + pK_{U'}\right) + \Delta f(p)\left(\frac{pK_{\Delta f}}{Tp+1} + pK_{f'}\right) + \Delta I_f(p) pK_{I_f} \right) \cdot \frac{K}{T_y p + 1} \quad (1)$$

where $T=0.5s$, $T_y=0.2s$, $K=1$.

Fig. 1 presents block diagram of АРВ-СДП1 excitation system.

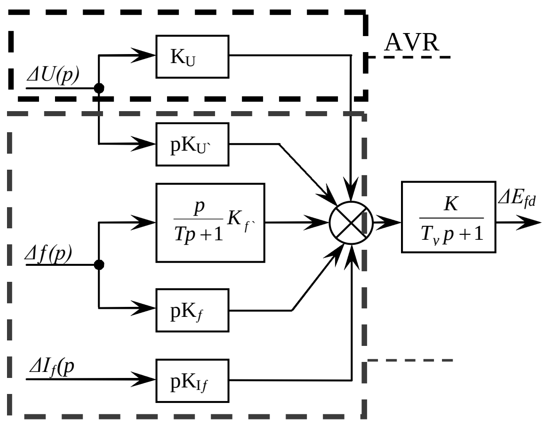

Fig. 1. Block diagram of АРВ-СДП1 excitation

3. Influence of PSS parameters to dynamic of control process

Simplified “machine-system” diagram (Kegums HPP and System) is presented in Fig. 2.

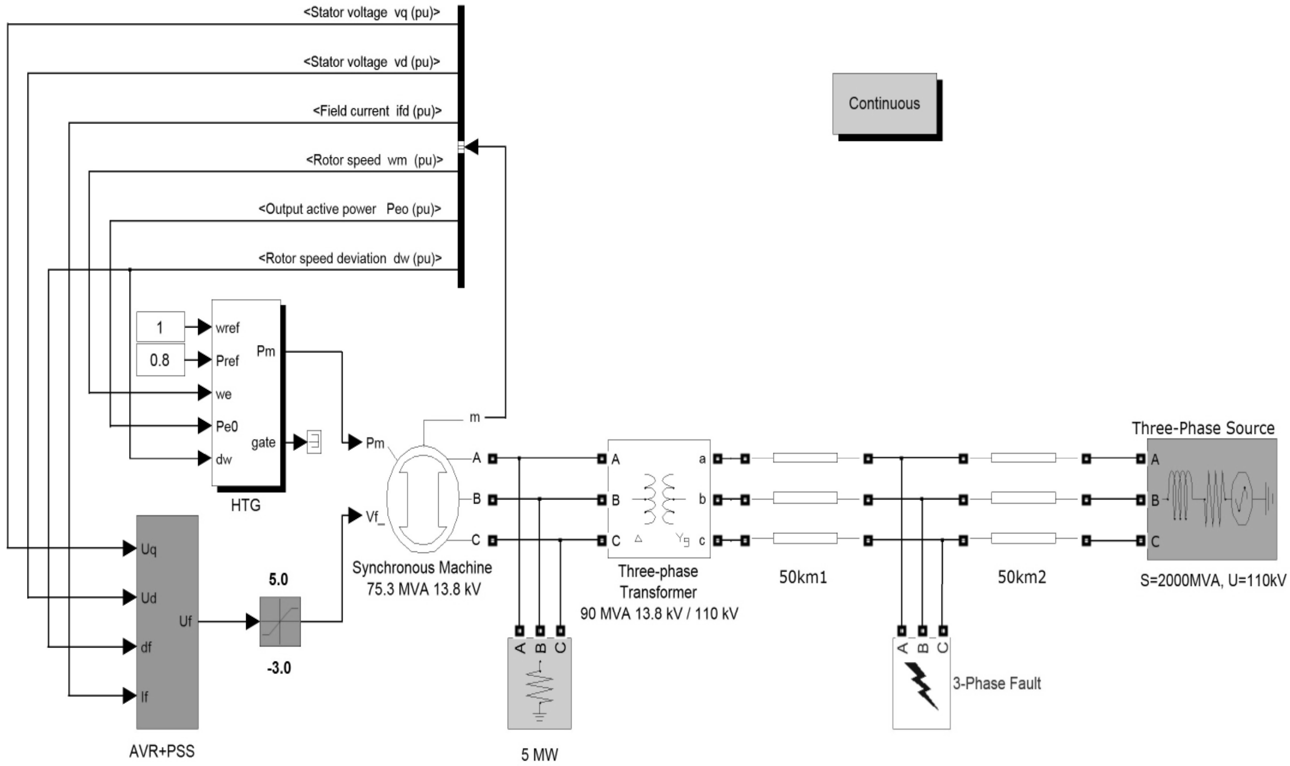

Fig. 2. Simulation model of Kegums HPP [6]

Generator is equipped with standard governor and automatic voltage regulator and connected to infinite bus through three-phase transformer and transmission line. Simulation model was developed using Matlab Simulink simulation software.

Model is equipped with block, simulating short circuit event. It simulates three-phase to ground short circuit. This type of short circuit selected as the heaviest case to study transient process.

The dynamic of power system transient investigated for three phase to ground for different duration of short circuit simulation.

In this case duration of short circuit is 0.3 seconds. Increase the duration causes out-of-step condition. Maximal short circuit duration depends on the load value in the power system [6].

For considered case load is represented by HPP auxiliaries. Increase of the load will increase maximal duration of the short circuit, but it will not influence optimization process of excitation system.

4. Optimization of excitation system

Results of research conducted by authors showed that existing parameters of excitation system are not optimal from the point of view the power oscillation damping. The influence of excitation system parameters to power damping was considered.

The following genetic algorithm as optimization criterion is suggested [3]:

$$\mathrm{A} = \alpha_1 \int_0^t \left| P_\mathrm{G}(t) - P_\mathrm{ref}(t) \right| dt + \alpha_2 \int_0^t \left| V_\mathrm{G}(t) - V_\mathrm{ref}(t) \right| dt + \\ + \alpha_3 \int_0^t \left| f_\mathrm{G}(t) - f_\mathrm{ref}(t) \right| dt \qquad (2)$$

where P_G denotes the active power, P_{ref} is its desired value; V_G and V_{ref} are the terminal voltage and its desired value, f_G denotes the frequency, f_{ref} is desired value.

The values of quantities used in equation (active power, voltage and frequency) are different. So deviation of one parameter will always exceed others. For unbiased estimation of optimization system it is possible to divide multi-objective equation into few simple equations and analyze each taken separately [5]. Comparison of simple equations can develop recommendations for optimization of the system. Optimization criteria can be:

$$\mathrm{A}_1 = \int_0^t \left| P_\mathrm{G}(t) - P_\mathrm{ref}(t) \right| dt \to \min \qquad (3)$$

$$\mathrm{A}_2 = \int_0^t \left| V_\mathrm{G}(t) - V_\mathrm{ref}(t) \right| dt \to \min \qquad (4)$$

$$\mathrm{A}_3 = \int_0^t \left| f_\mathrm{G}(t) - f_\mathrm{ref}(t) \right| dt \to \min \qquad (5)$$

From the transfer function (1) it is seen that for different coefficients character of control is different. The real diapason of coefficients is:

$K_{\Delta U} = 15,25,50$ *(p.u.);*

$K_{U'}$ *= from* 6 *to* 8.5 *(p.u.);*

$K_{\Delta f}$ *= from* 11 *to* 14.4 *(p.u.);*

$K_{\Delta f'}$ *= from* 4 *to* 5.5 *(p.u.);*

$K_{I'_f}$ *= from* 2 *to* 3 *(p.u.)*

Table 1 illustrates combination of coefficients used for the study of optimization the excitation system. Fig. 3 and 5 illustrate optimization results for excitation system when optimization criteria are A2 and A3. When criteria A1 and A3 are selected the most optimal variant is for parameters of variant 6 and criterion A2 gives best result with parameters of variant 10. There is need in selection priority of variant for coefficients P, f and U or to select compromise version.

Table 1. Variants of coefficients used for the study of optimization the excitation system of Kegums HPP

Nr	ΔU	ΔU'	Δf	Δf'	ΔI'f
1	15	6	11	4	2
2	25	8.5	11	4	2
3	15	8.5	14.4	4	2
4	50	6	11	5.5	2
5	25	6	14.4	5.5	2
6	15	6	11	4	3
7	50	8.5	11	4	3
8	15	8.5	14.4	4	3
9	25	8.5	14.4	4	3
10	15	8.5	11	5.5	3
11	50	6	14.4	5.5	3
12	50	8.5	14.4	5.5	3

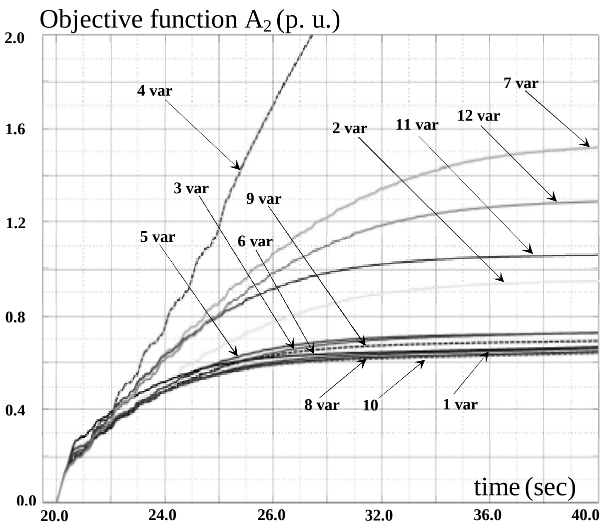

Fig. 3. Variations of objective function A2 for different variants of coefficients during short circuit

Fig. 4 and 6 illustrate results of parameters' optimization. Transient processes for voltage and frequency variations are shown for different optimization parameters.

Application the coefficients of variant 4 will cause out-of-step condition. The best damping case is observed for application of variant 6.

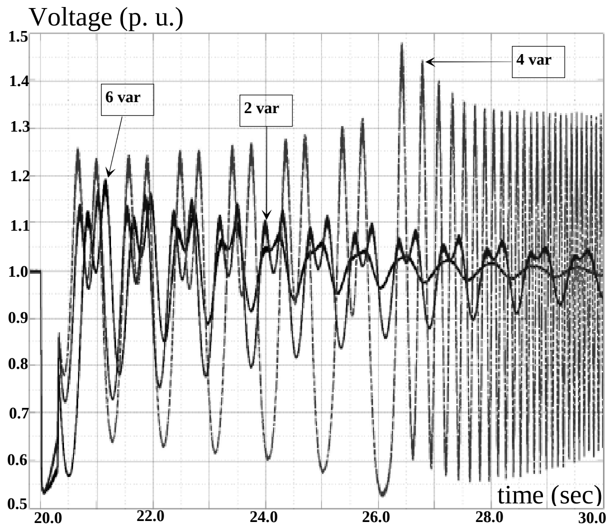

Fig. 4. Variation of Kegums HPP generator's voltage depending on combination of control coefficients

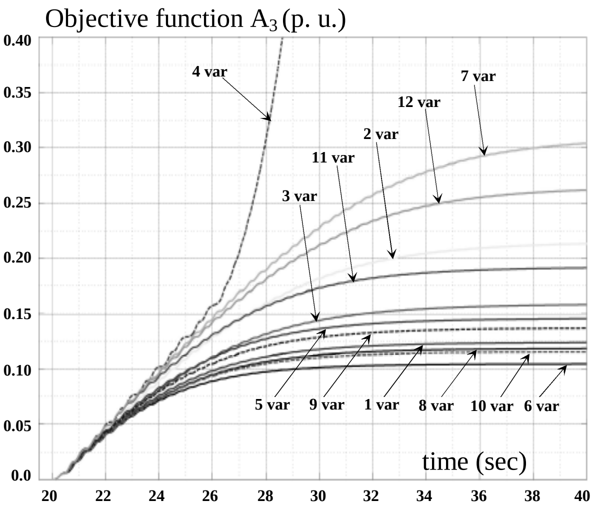

Fig.5. Variations of objective function A3 for different variants of coefficients during short circuit

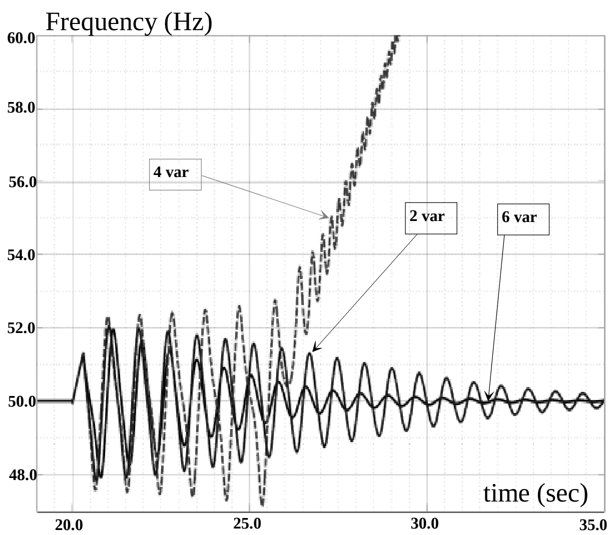

Fig. 6. Variation of Kegums HPP generator's frequency depending on combination of control coefficients

5. Adaptive approach for control of excitation system

The next step of research was verification of optimal parameters' selection when influence of a neighbor power plant is investigated. The design diagram of the Latvian power supply system represents the mathematical model which is constructed with PSS/E software.

The excitation system presented in Fig. 1, was integrated into simulation model of the Latvian power system.

Fig. 7. represents investigated network of the Latvian power system. For practical analysis of dynamic behavior during disturbances in the power system each plant is represented by an equivalent generator.

Optimization criteria search was determinated at three-phase to ground short circuit, with duration 0.3 seconds.

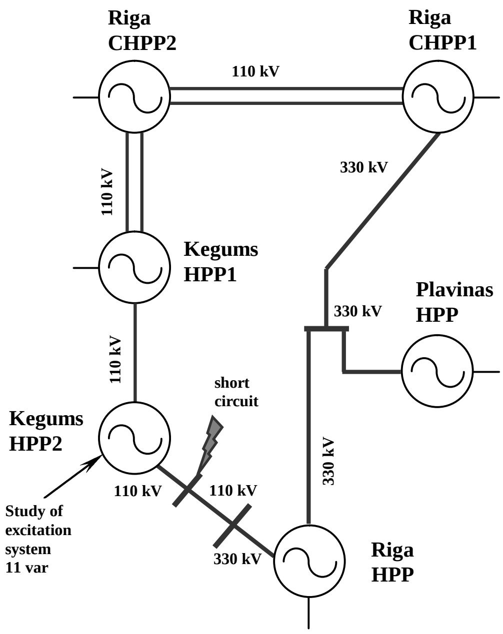

Fig. 7. Simplified diagram of interconnected power plants

The fault location was chosen the same distance to Kegums HPP as represented in Fig. 2. Short circuit's location is at 110 kV substation (Ķekava).

Variations of objective function A2 for different variants of coefficients are illustrated in Fig. 8.

Fig. 8 shows that parameters of variant 3 are the most optimal. Two worst parameters of transient process are for variants 6 and 11.

Results of voltage investigation on the bus of the Kegums HPP's synchronous generator at transient process moment (Fig. 9), shows that at parameters of variant 6 there is a significant voltage drop.

For parameters of variant 11 at the moment of voltage recovery occurs visible overshoot (voltage raise).

In turn, comparing voltage raise at parameters of variants 3 and 11, it is possible to reduce overshoot by 5%.

Using objective function A1 (Fig. 10) parameters of variant 10 are most optimal, but the worst is 11 variant.

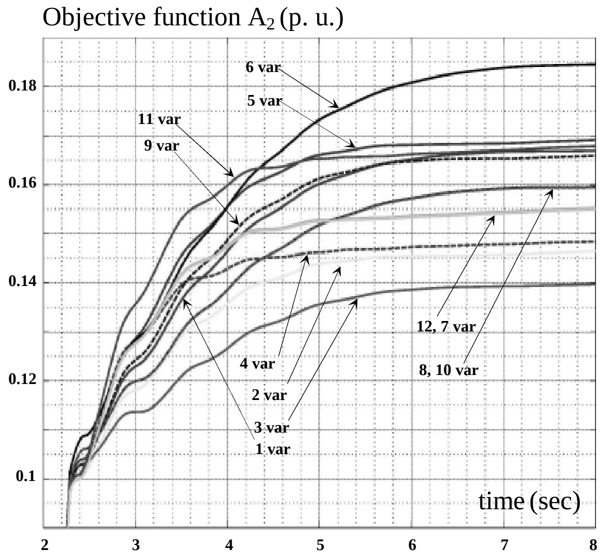

Fig. 8. Variations of objective function A2 for different variants of coefficients during short circuit

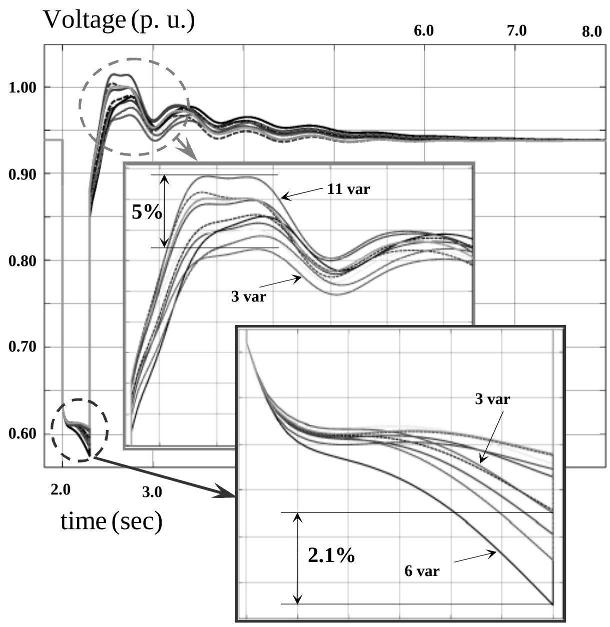

Fig. 9. Variation of Kegums HPP generator's voltage depending on combination of control coefficients

Active power's characteristics for different variants of coefficients are illustrated in Fig. 11.

Comparing variants 10 and 11 is visible that deviations from nominal value can be reduced by 14.7 % (the top value) and on 27.0 % (the bottom value).

Last objective function is shown in Fig.12. Like the second criterion, parameters of variant 10 are most optimal, but the worst is 11 variant.

Frequency's characteristics for different variants of coefficients are illustrated in Fig. 13.

Using variant 10 in comparison with variant 11, allows to reduce frequency's deviation from nominal value (raises damping).

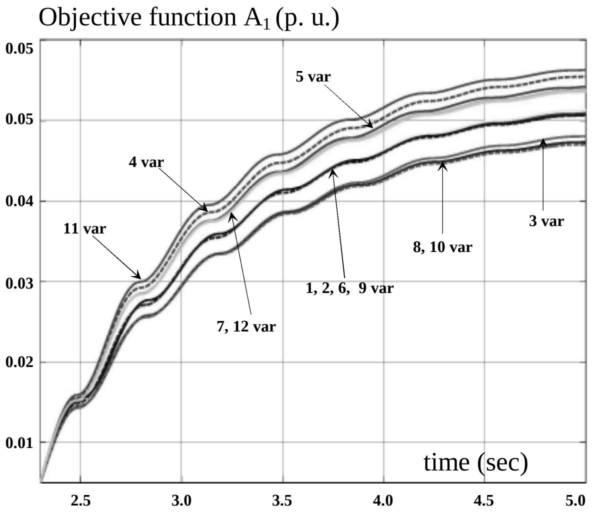

Fig. 10. Variations of objective function A1 for different variants of coefficients during short circuit

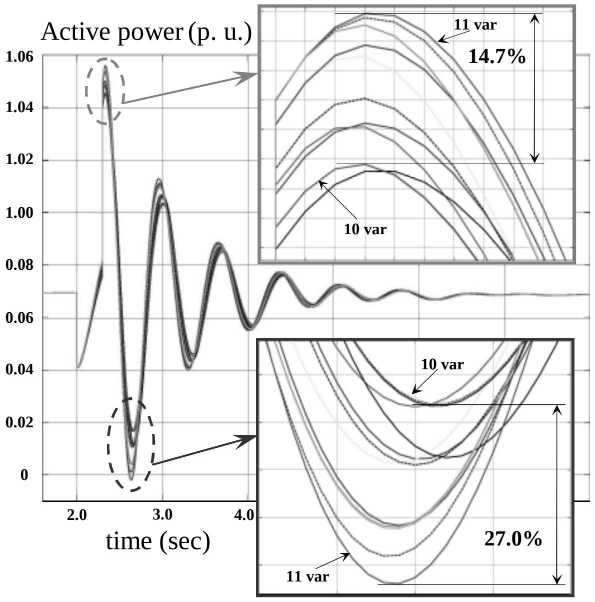

Fig. 11. Variation of Kegums HPP generator's active power depending on combination of control coefficients

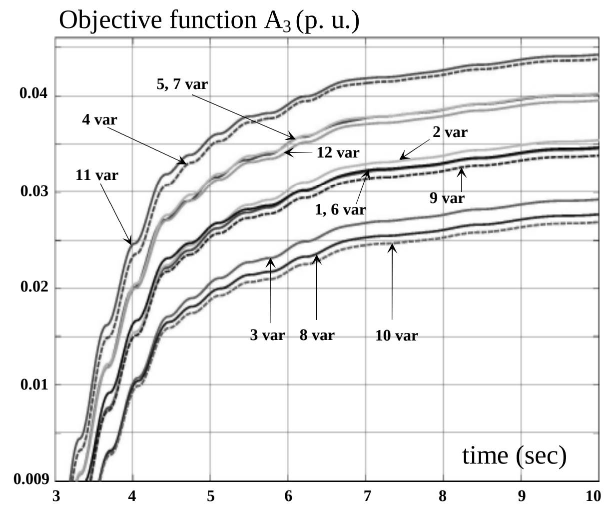

Fig. 12. Variations of objective function A3 for different variants of coefficients during short circuit

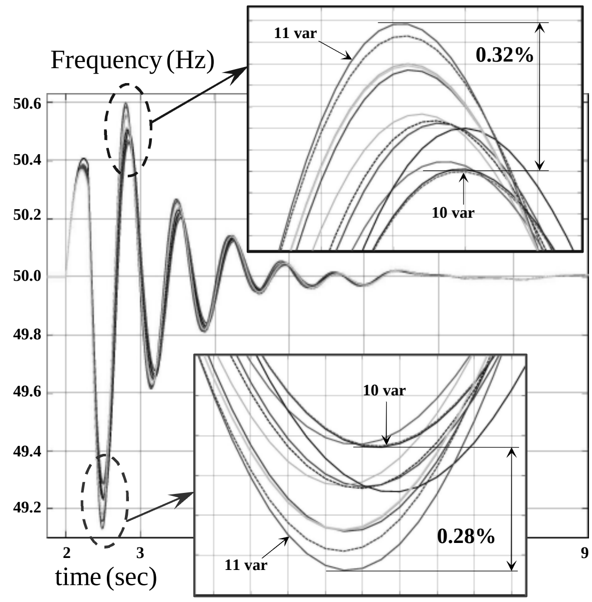

Fig. 13. Variation of Kegums HPP generator's frequency depending on combination of control coefficients

6. Conclusions

1. Influence of PSS parameters to dynamic of control process was investigated.
2. Optimal parameters for Kegums HPP were selected using genetic algorithm.

The investigations done using simplified scheme Fig. 2 show that criteria (3), (4), (5) are possible to improve synchronous generator’s output parameters’ damping and in some cases can prevent out-of-step condition Fig. 4, 6.

3. Influence of neighbor operating power plants' parameters was considered from the point of view stability of excitation control.

Influence of neighbor power plant’s parameters is significant. The results of investigations which are done using simulation model of the Latvian power supply system, show that optimization of Kegums HPP’s excitation system’s parameters can increase stability and efficiency. Possibility of damping increasing of synchronous generator’s output parameters is illustrated in the paper. For example, active power’s amplitude’s reducing on 14.7 % and on 27.0 % in the first period (Fig. 11).

7. References

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