Method of determining the optimal settings of automatic excitation regulators of synchronous machines in EPS

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Abstract. The stability of the electric power system can be improved by forming of the correct settings of automatic exciting regulators. Currently, there is no unified methodology of automatic exciting regulators, so analysis of their impact is still an urgent task. The article describes the approach to solving above-mentioned problem, which combines several methods. Research based on Hybrid Real Time Simulator of EPS developed in Tomsk Polytechnic University.

1. Introduction
Normal and stable operation of electric power systems (EPS) is largerly determined by quality of tuning parameters of automatic voltage regulators (AVR) of synchronous machines. The increasing of damping time of transition (emergency) processes in EPS and the emergence of synchronous oscillations, which can lead to an asynchronous operation, are the result of improper adjustment of AVRs. [1]. Since all the processes in the power system are interrelated, and the adjustment of regulators for a generator (generator groups) have an impact on processes in other parts of the power system. Therefore, changing (improving) the adjustment parameters for the AVR of the generator can observe degradation of the regime in other parts of the power system, if before they were tuned optimally. Therefore the problem of an complex approach of the optimal determination of AVRs settings of generator units is still relevant.

2. Materials and methods
Existing approach of optimal settings determination of the AVRs the includes several methods, each of which has some disadvantages:

1. Instructive materials and recommendations. Recommendations and guidelines are developed by the task of adjusting parameters of AVR based on large practical and theoretical experience, which usually includes only ranges of variation these parameters, but doesn't regulate their exact values [2].
2. Determination of optimal parameters by field tests in EPS. This approach is often used by staff of small power plants. However the unjustifiably high risk of accidents and the lack of long-term positive results limit the application of such an approach [3].
3. Testing AVR on simplified network models [4-6]. This is the most modern approach of functional testing and determination of optimal values of parameters AVR. It allows to perform complex inspection the whole station excitation and functioning of protection systems. The equivalenting and using of simplify EPS in particular one generator (bus of infinite capacity) and

communications link that leads to wrong settings in channels of voltage derivatives, excitation current and frequency are the main disadvantage of this approach.

4. Mathematical modeling. The simulation software should calculate the dynamic modes of EPS for reliable determination of the influents of adjustment AVR parameters to oscillatory stability of EPS. However, limitations of the EPS model size and the time step simulation, which should take into account the guaranteed simulation of the electromagnetic processes in mathematical models of AVR (and equipment of EPS in general), don't provide the results in a reasonable time. Another limitation of numerical methods is the accumulation of errors resulted the loss of simulation data [7, 8].

The article describes the approach to solving above-mentioned problem, which combines all the above methods and based on Hybrid Real Time Simulator of EPS developed in Tomsk Polytechnic University [9]. This simulation approach allows to reproduce the three-phase dynamic processes of modeled EPS without errors of numerical methods, as well as to connect to it with various external devices via analog and digital interfaces, such as excitation station. Thus the modeling of processes of EPS is made in real-time on mathematical models, the station of excitation may be connected to Hybrid Real Time Simulator of EPS or reproduced on a built-in model [10], determination of optimal parameters AVRs produced by algorithms automated scripts, and the initial parameters are set on AVR guidance material.

It is necessary to perform only two requirements for the simulated EPS to ensure accurate reproduction of all the processes in the EPS: the similarity of structure and parameters (design and adjusting). This is related to the fact that the mathematical models used in the Hybrid Real Time Simulator of EPS contains fairly complete and detailed description of all power facilities.

It is important to set the disturbance and control of the selected criteria to perform optimization. As the disturbance using pulse frequency change of tires infinite capacity (system, G-1, figure 1). Optimality criteria are the following factors: the lack of asynchronous operation and minimizing decay time of transition for most indicative parameters of synchronous machines, such as:

- Frequency (ω, Hz)
- Voltage of excitation winding.

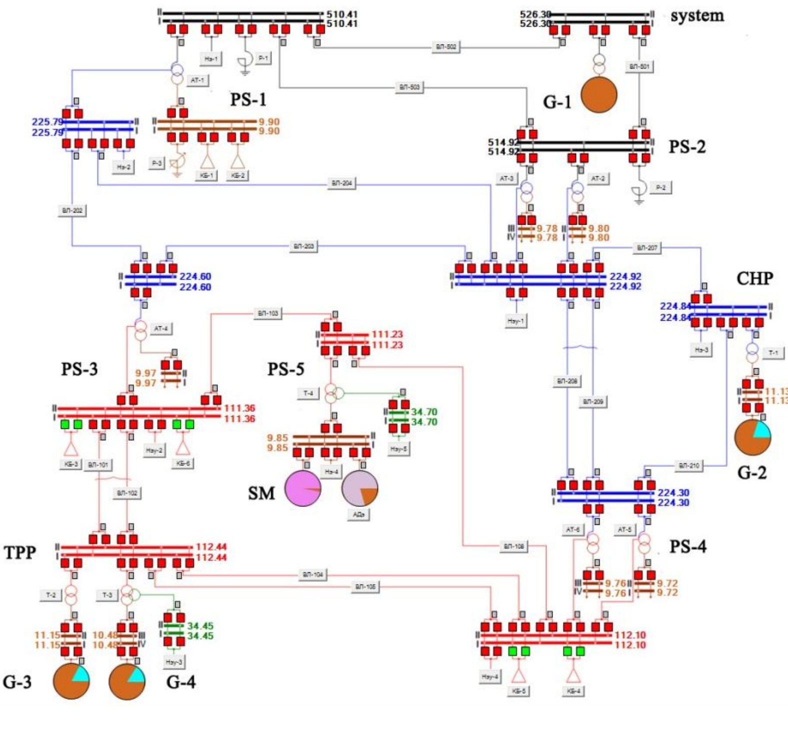

Figure 1. Scheme the simulated power system.

The scheme of simulated EPS is shown in Figure 1.

Synchronous oscillation occurs in the simulated power system with total for the entire power system perturbations in the form of a pulse frequency changes of infinite capacity bus, which lead to the asynchronous operation of synchronous motor (Figure 2).

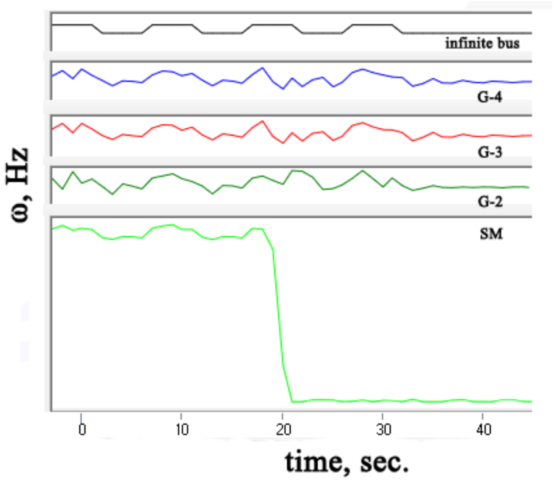

Figure 2. Frequency characteristics.

Determining the optimal settings AVRs produced by a successive approximation algorithm for each value of the adjustment parameters AVR of all synchronous machines, at which measured decay time of electromechanical transients in EPS. Minimizing the decay time is the criterion of determining the optimal parameter values AVRs. In Figure 3 shows the excitation voltage Uf and frequency ω. Figure 3 shows that Uf on G-2 is set longer than other values, so the decay time is determined for this parameter.

3. Results

Implementation of the method is shown by the example of the synchronous machine (SM) in the substation 5. Figures and graphics transient dependencies are shown below.

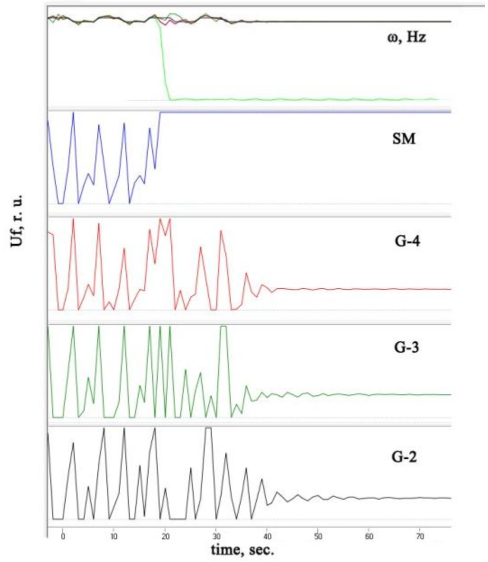

Figure 3. The dependence of the excitation voltage from the oscillation frequency.

In Figure 4 shows the effect of parameter kΔU changes in the excitation voltage Uf in the studied electrical machines. Minimum damping time shaded gray that corresponds value kΔU = 5.

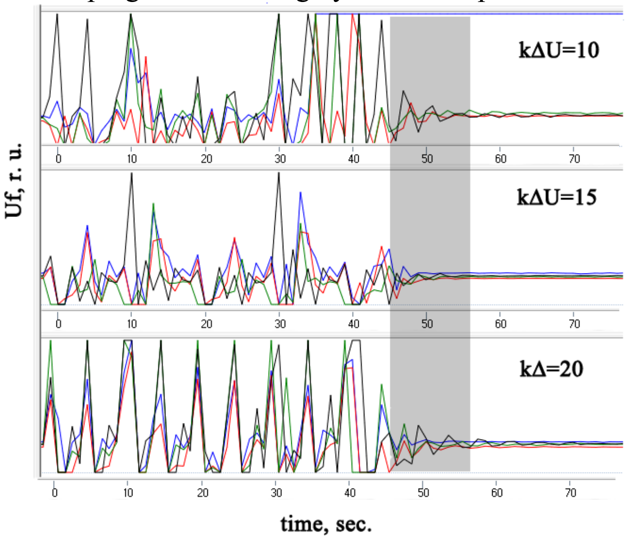

Figure 4. Dependence Uf from the kΔU.

Figure 5 shows a graph of the damping time of the setting kΔU on SM. Black dotted lines show the values at which occurs asynchronous operation of the synchronous motor. The decay time is equal to 100 seconds conditionally.

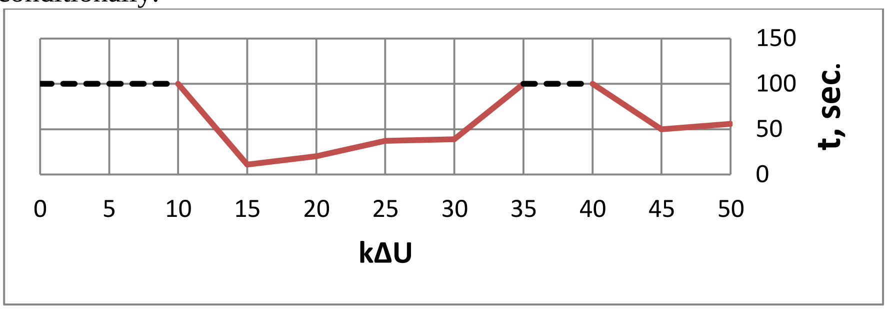

Figure 5. The dependence of damping time from the kΔU.

This experience is done sequentially for each of the synchronous machine with the new parameters, as a result, is possible to determine optimal values of kΔU.

As a result of the installation of optimal adjustment parameters of AVR, damping time was 10 seconds. In Figure 6 shows the results of researches demonstrating the effectiveness of methods.

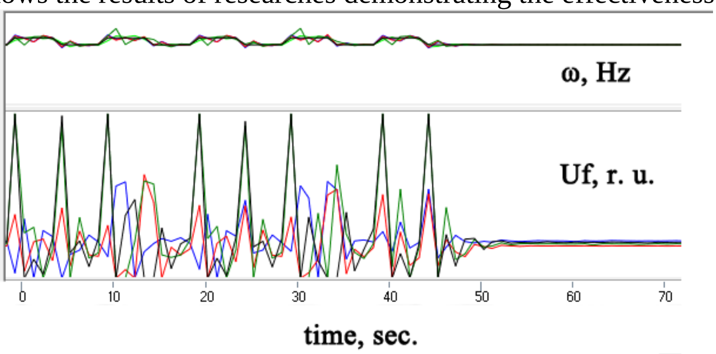

Figure 6. Results of research

The optimal parameters of AVR are determined for a particular scheme-modal state modeled power system as a result of automated scripts. Accordingly, when it changes the process of finding the optimal values is repeated which gives statistical material to determine the optimum parameters of AVR across the spectrum of modes of power system and development of appropriate recommendations.

4. Conclusions

Results of the practical experiments show the linkages adjustment parameters AVR of different synchronous machines included in the simulated power system. Consequently, when setting AVR for a particular generator or stations necessary to consider the current parameters of AVRs other synchronous machines, especially those with strong electrical interconnections.

To determine the optimal parameters AVRs necessary to consider all the features of the power system (or the local power district) as detailed as possible, otherwise the numerical values of the parameters will be defined incorrectly. The extent and nature error may lead to a radical difference between the processes at work of AVR in the real grid.

Only one criterion is used in the work as the optimal parameter settings to minimize the time of AVR. This is minimization of time of electromechanical oscillations. However, such criteria may be set (range of voltage and reactive power generation and other user-defined requirements).

References

[1] Merkuriev G 2008 *Stability of power systems* (St. Petersburg: Training Center of Energy)
[2] Portnoy M *Methodical instructions on determination of stability of power systems* Part 2 (Moscow: Soyuztehenergo)
[3] Lirin V 1968 *Setting and experimental works ORGRES* **35** 255-262
[4] Yurganov A and Kozhevnikov V 1996 *Excitation control of synchronous generators* (St. Petersburg: Science)
[5] Zhdanov P 1979 *Questions of the stability electrical* (Moscow: Energy)
[6] Venikov V 1985 *Transitional electromechanical processes in electrical systems* (Moscow: Higher school)
[7] Chernikh V 2008 *Simulation of electrical devices on Matlab, SimPowerSystem and Simulink* (Moscow: DMK Press)
[8] Gusev A, Khrushchev A, Gurin S, Svechkarev S and Plodisty I 2009 *Electricity* **12** 7-9
[9] Gusev A, Svechkarev S and Plodisty I 2004 *Electricity and the Future of Civilization : Materials of the International Scientific and Technical Conference* pp 329-330
[10] Ilina A and Svechkarev S 2014 *Electrical power industry by eyes of youth: collection of reports of V International youth Scientific and Technical Conference* pp 503-507
[11] Kosuke N, Kiyosi T and Masuo G 1997 *Elec. Rev* 82 **5** 67-71
[12] Akihiro A 1998 *Trans. Ing. Elec. Eng* 118 **4** 360-363