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ANALYSIS OF METHODS FOR STUDYING THE STATIC STABILITY OF A GENERATOR WITHOUT AUTOMATIC EXCITATION CONTROL

The study of electromechanical transients in electrical systems allows us to predict the occurrence of any transient process, preventing possible negative consequences [1, 2]. The following methods are used to study the static stability of power systems: numerical methods, computer simulation methods, and algebraic methods.

Numerical methods such as finite element analysis and finite difference methods can be used to solve complex mathematical equations and simulate the behavior of energy systems under different conditions. These methods can be computationally intensive but can provide highly accurate results [3].

Computer simulation methods can also be used to model and simulate the behavior of energy systems. These methods involve the use of computer programs to model the system's components, inputs, and outputs. By simulating the behavior of the system under different conditions, these methods can provide insights into potential stability issues and ways to optimize system performance [2, 4].

Algebraic methods such as power-flow analysis and load-flow analysis are widely used in the energy industry to study the static stability of power systems. These methods involve the use of algebraic equations and mathematical relationships to model the system's behavior and determine its stability under different conditions [1, 5].

The choice of method will depend on the specific problem being addressed and the resources available. For instance, algebraic methods may be more suitable for studying the steady-state behavior of large power systems, while numerical and simulation methods may be more appropriate for analyzing the dynamic behavior of smaller systems or for simulating the effects of extreme events such as storms or blackouts.

Static stability is the ability of a given steady-state mode to self-establish after the end of the action of small disturbances in the parameters of this mode, and not to "slip" from them, as well as to withstand small disturbances during the gradual deterioration of the mode close to the limit. Small disturbances always accompany the operation of the system and are mainly associated with changes in load, as well as with the reaction of regulating devices to this; with the switching on and off of individual generators or changes in their power; with changes in normal operating schemes during switching, etc.

The task of analyzing the static stability of the system is solved by determining the dependencies that characterize the change in the parameters of a given output mode over time under small disturbances of this mode. In most cases, it is sufficient to determine the change in the rotor runout angle of the SG rotor over time. To do this, it is necessary to solve the nonlinear differential equation (1) (or a system of differential equations) that describes this mode. It is impossible to find a solution to equation (1) in general. Therefore, the stability study is carried out either by integrating the linearized differential equation using the method of small oscillations or by direct integration of the original nonlinear differential equation using numerical methods.

$$\frac{T_j}{\omega_0}\cdot\frac{d^2\delta}{dt^2}+\frac{P_d}{\omega_0}\cdot\frac{d\delta}{dt}=P_0-\frac{E_q\cdot U_c}{X_c}\cdot\sin\delta, \quad (1)$$

where *Tj* is the rotor inertia constant, s;
Pd is the damping coefficient, d.u;
P0 is the power of the turbine at the initial steady-state mode, units;
δ is the generator rotor runout angle, rad;
$\omega 0$ is the synchronous rotor speed, rad/c,
Eq is the transverse synchronous EMF of the generator, in units of time;
Uc is the voltage on the buses of the receiving system, voltages;
Xc is the sum of the resistances of the transmission elements from the point of application of the EMF Eq to the busbars of the receiving system with a voltage *Uc*, voltages.

The simulation model of the synchronous generator movement with measurement circuits developed in this paper is shown in Fig. 1.

As a result of the studies, the problem of analyzing the static stability of a synchronous generator without automatic excitation control in a wide range of changes in output parameters was solved. Dependences of the rotor runaway angle of a synchronous generator in time were obtained.

The developed software system is used in the educational process of the Department of Power Supply of Industrial Enterprises of the National University "Zaporizhzhia Polytechnic" in the study of the discipline "Electromechanical Transients" for students of specialty 141 "Electric Power Engineering, Electrical Engineering and Electromechanics".

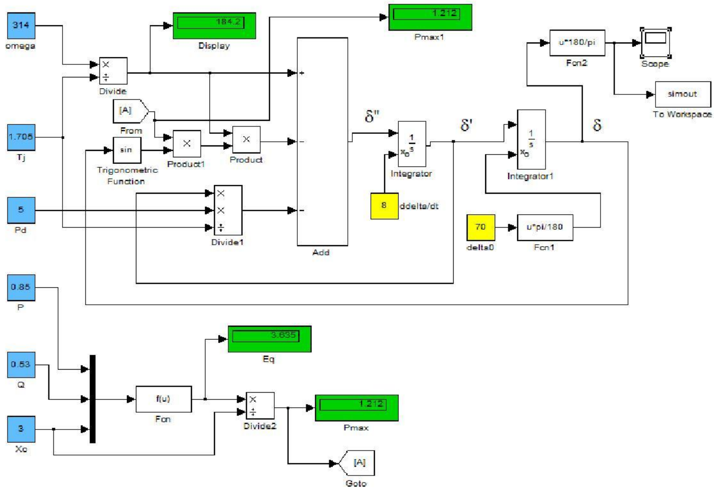

Figure 1 – Simulation model of synchronous generator movement

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