

Research of a Computer Model of a Synchronous Hydroelectric Generator

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Abstract— In this work, a computer model was developed to research the operation of a hydrogenerator in normal and emergency modes during its operation on a consumer load or as part of a power system.

Keywords— hydrogenerator, control system, computer model.

For connection to the mains, the model has terminals of stator windings A, B, C. Also, the model has two inputs: Pm signal (in relative units (r.u.)), which corresponds to the mechanical power on the shaft of the machine; vf is the signal that determines the voltage of the excitation winding (also in r.u.).

The synchronous generator model has an information output m, where a vector signal is formed and its components characterize the operation of the machine. The Structural scheme of the computer Simulink model of the synchronous generator is developed, taking into account the presence of the excitation system is shown in Figure 2.

I. THE MAIN MATERIAL OF THE ARTICLE

The equations of state of the synchronous electric machine [1... 4] are implemented in the computer model of the synchronous generator shown in the figure 1. The structural model consists of a subsystem of the electrical part (electrical model) and the mechanical part (mechanical model) [5, 6].

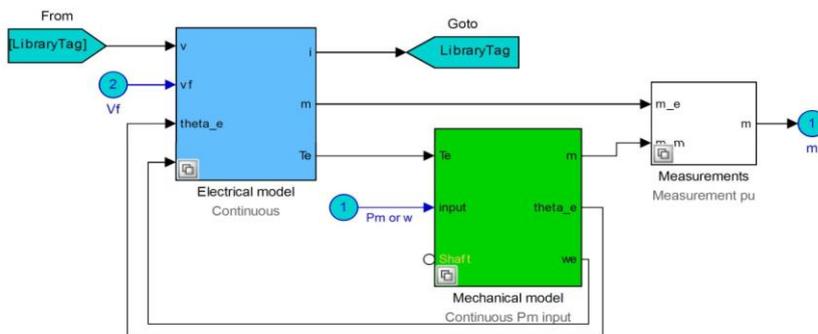


Figure 1. A computer model of a synchronous power generator

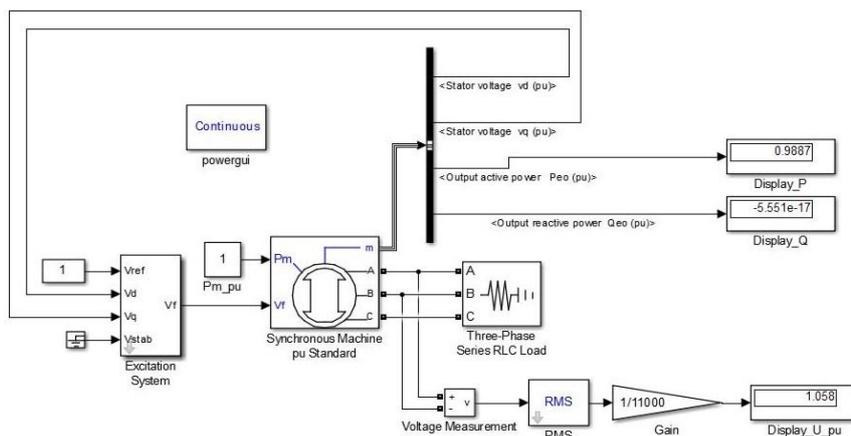


Figure 2. Structural scheme of a computer model of a synchronous generator, taking into account the presence of an excitation system

The current values of the generator stator voltage projections are transmitted from the generator parameter measurement unit to the corresponding inputs of the Excitation System unit. The case of generator operation in nominal mode is considered. The input V_{ref} (the required value of the voltage at the clamps of the stator of the synchronous generator) is given a value of 1 r.u. The synchronous machine power stabilization circuit is not intended to be created, so a zero signal is output to the V_{stab} input.

The generator is loaded with an active load of 36 MW, the reactive component of the load is zero. From the readings of the measuring instruments it is possible to establish that the synchronous generator operates in the nominal mode: it gives an active power of 0,99 r.u. The linear voltage at the clamps is 1,06 r.u.

The model of the synchronous generator of the hydroelectric power station connected to the 110 kV network is shown in figure 3. The Hydrogenerator subsystem (Figure 2) provides the measurement of instantaneous (u) and operating (U_{rms}) values of the linear voltage at the output of a synchronous generator, with measurements being made in relative units. Hydrogenerator subsystem realizes the possibility of measuring the active and reactive power of a synchronous generator in r.u. For this purpose, we use the values of phase voltages and currents in three phases, which in vector form is fed to the Power unit, which outputs P a vector whose elements correspond to the active phase power, and Q outputs a vector whose elements correspond to reactive power. The sum of the elements of each vector is determined by the Sum of Elements units, which allows to determine the active and reactive power of the three-phase system. Power outputs of subsystems A, B, C and correspond to the outputs of the stator winding of the synchronous generator.

The model of the synchronous generator of a hydroelectric power station connected to the 110 kV network in addition to the Hydrogenerator subsystem also includes the model of the power-boosting unit transformer (Three-Phase Transformer) and the Source unit, which models the 110 kV power system, whose power is selected at 10000MVA.

The connection of the hydrogenerator to the power system is provided by the Breaker2 high-voltage switch. By operating this switch, it is possible to investigate the operation of the hydrogenerator on the system or on a consumer load.

The output of the unit transformer, through high-voltage switches Breaker3 and Breaker4, is connected by two identical active-inductive loads Load1 and Load2. The value of each load is 50% of the power of the hydrogenerator.

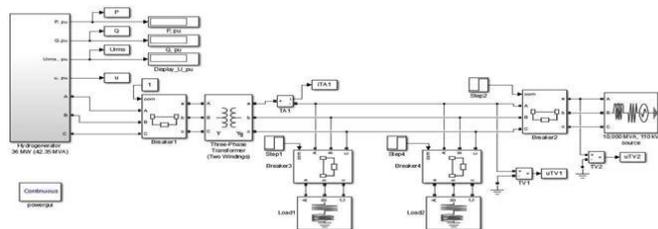


Figure 3. Structural scheme of Simulink model of synchronous generator of hydroelectric power station connected to 110 kV network.

The obtained model makes it possible to investigate the peculiarities of functioning of the hydrogenerator both on the consumer load and in the composition of the power system. The valid structure of the model of the synchronous generator of a hydroelectric power station connected to the 110 kV network contains the calculated values of the parameters of the elements.

Consider the operation of the hydrogenerator of a hydroelectric power station on a consumer active-inductive load. To do this, in the model scheme (Figure 3.) it is necessary to ensure that the Breaker2 switch is switched off, which disconnects the generator and loads Load1 and Load2 from the network. To do this, the Step2 unit must produce a zero signal during the simulation time. The initial state of the other switchgear is as follows: Breaker1 - on, Breaker3, Breaker4 - off. This ensures that the generator is idling.

The simulation is carried out in the following sequence: at the time of model time $t_1=1s$ the Breaker3 switch is switched on, which ensures that Load1 is connected to the generator. At time $t_2=2s$, the Breaker4 switch is switched on to provide a Load2 load connection. As a result of simulation, the graphs (Figure 4.) of the active power of the generator P , r.u. the reactive power of the generator Q , r.u. and the active value of the load voltage U_1 , r.u. are obtained. The analysis of graphs allows to establish the fact of functioning of the hydrogenerator in idle mode in the absence of load, ie up to the moment $t_1=1s$. The voltage at the output of the generator corresponded to the idle voltage of 1,1 V. When connected at the time $t_1=1s$ active-inductive load, the value of which is 0,5 of the rated load of the generator, the active power given by the generator increases to the level of 0,5 r.u. At the same time, the jet power is increased to 0,5 r.u. This can be explained by the fact that some of the reactive power is consumed by the step-up unit transformer. The voltage in the system under consideration is reduced accordingly to the level of 1,05 r.u.

When connected to the Load2 generator with the Breaker4 switch at the time $t_2=2s$, the power from the generator increases to the nominal level, the voltage at the generator also becomes the nominal level.

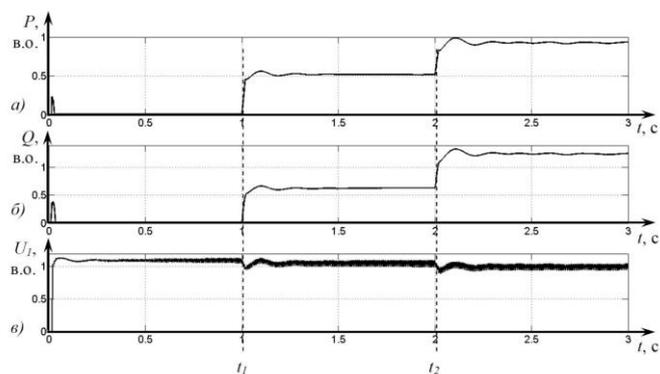


Figure 4. Graphs as a function of time t , showing the functioning of the hydrogenerator on the consumer active-inductive load: a) - active power of the generator P , r.u.; b) - reactive power of generator Q , r.u.; c) - the current value of the voltage on the load U_1 , r.u.; t_1 - moment of connection of load Load1 by Breaker3 switch; t_2 - load connection time of Load2 by Breaker4 switch.

Let us analyze the possibility of adjusting the voltage level at the output of the generator. For this purpose, under the

conditions of the previous experiment, at the moment of model time $t_3=3s$, we will change the signal level at the input V_{ref} (the required value of the voltage at the stator holders of the synchronous generator, r.u.) of the excitation system of the synchronous machine: the signal will be increased from 1 r.u. up to 1,2 r.u. The excitation control system will work out a change in the signal of the task and provide a corresponding increase in the excitation voltage of the generator, which causes an increase in the voltage amplitude at the output of the hydrogenerator. The graph of instantaneous voltage values is shown in Figure 5. From this graph it is possible to establish that until the moment $t_3=3s$ the amplitude values of the voltage at the output of the generator corresponded to 1 r.u., after the change of the task signal an oscillatory transient occurs, which lasts about 0,25s. The change in the amplitude value of the voltage is 17%. The constant amplitude of the generator output voltage is 1,2 r.u.

In the model shown in figure 3, a three-phase switch of short circuit was additionally connected to Load1 load line, which allowed modeling of processes in an autonomous power system at a three-phase short circuit. The graphs characterizing this mode are shown in figure 6.

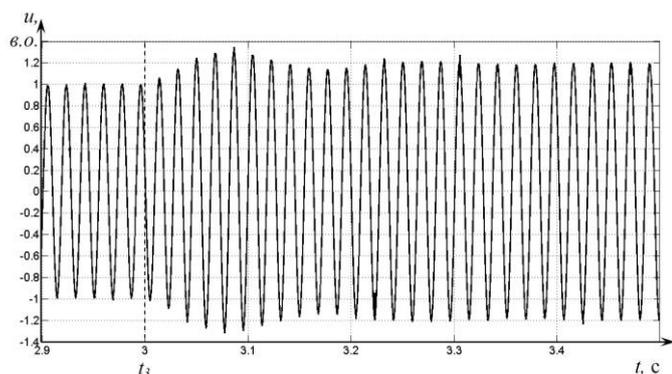


Figure 5. Instantaneous voltage values (in r.u.) on the consumer load of the hydrogenerator when increasing, by means of the excitation system of the synchronous machine, the value of the voltage of the generator from 1 r.u. up to 1,2 r.u. at the time of model time $t_3=3s$.

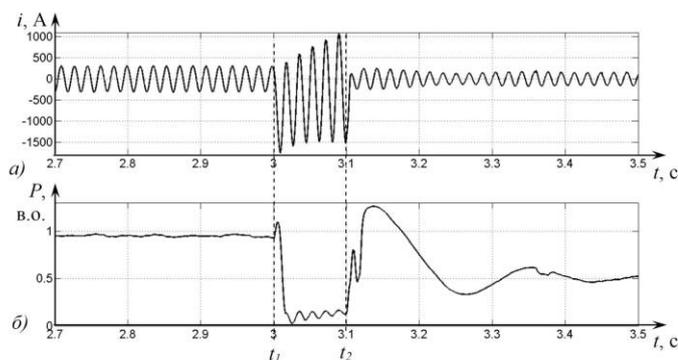


Figure 6. Graphs as a function of time t , characterizing the processes in the autonomous power system at three-phase short circuit in the load line of Load1: a) - instantaneous values of generator current, A; б) - value of the active power of the generator, r.u.; t_1 - moment of occurrence of r.u.; t_2 - moment of switching off of Breaker3 switch by signal of relay protection.

The occurrence of a short circuit at time $t_1=3s$ is accompanied by a significant increase in the generator current, and, as can be established from the graph to Figure 6 a, this current contains both periodic and aperiodic components. At time $t_2=3,1s$, the signal of relay protection disconnects the cell of the damaged line, which restores the normal operation of the system.

Also, the developed model makes it possible to study the functioning of the hydrogenerator within the system. This mode is enabled by the Breaker2 switch state, which connects the generator and load Load1 and Load2 to the network.

CONCLUSION

The proposed computer model allows us to research the operation of the hydrogenerator in normal and emergency modes, under consumer load, or as part of a power system. The model allows to obtain graphs of instantaneous values of currents, voltages, generator speed, active power.

As a result of research of the operation of the generator on the consumer load the following is established:

- when the generator is running in idle mode, the voltage at the generator output is 1,1 r.u., and when connecting the nominal load - 1 r.u.;
- the control system of excitation provides regulation of the output voltage of the generator for a time of about 0,25 s with an overregulation of 17%;
- three-phase r.u. in the power line of the autonomous load is characterized by the shock value of the current r.u. 1750 A.

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